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Saving Scarce Materials

DURING recent years, the output of manufactured goods has risen to such an extent that the production of the raw materials from which they are made has been unable to keep pace. In addition, the substantial measure of rearmament which the Western Powers have decided upon is increasing the rate of consumption of many materials, some of them already in the "scarce" category, and has thrown into greater prominence the danger, previously inadequately appreciated, of increasing stringency of supply. Such a situation which, if unheeded, would deteriorate with alarming rapidity, calls for immediate and drastic treatment. There are, obviously, two ways of tackling the problem: by increasing the availability of the raw materials; or by reducing the demand for those materials in short supply. Both aspects were considered last month at a General Discussion on Metal Economics, arranged by the Institute of Metals at the suggestion of the President, Professor A. J. Murphy. Elsewhere in this issue, we present an account of the afternoon session of the meeting, at which scrap reclamation, secondary metals and substitute metals formed the basis of the discussion. The omission of reference to the proceedings at the morning session is not intended to minimise the importance of long-term surveys and planning, but rather, in the space available, to concentrate attention on those matters to which immediate attention should be given if any early improvement is to be obtained.

The increase in supplies of raw materials is undoubtedly a long term remedy as there seems little likelihood of improvement in the very near future except, perhaps, in the case of aluminium and magnesium, which may prove useful in substitution for other materials. On the other hand, there must be many instances when we are not making the best use of the materials available, and the present situation is a challenge to designers, production engineers and metallurgists alike. Although much of the careful husbandry necessarily exercised in Britain during the war years has been continued, it was felt that nothing should be left undone which could help in conserving materials in short supply. Accordingly it was decided to send a Specialist Team on Scarce Materials to the United States in June and July of this year.

From a reading of the Team's Report—"Saving Scarce Materials,"* in which is presented a detailed discussion, material by material, of the progress which is being made in the way of substitution and dilution as a means of conservation, it seems that considerable mutual benefit must result from this visit, for whilst we should do well to follow American practice in certain fields, there are others in which British developments and British experience can be of help to the United States. In this connection, special reference is made to three new British techniques which should be made more widely known in America. They are: (*a*) the electrodeposition of tin-zinc and tin-nickel coatings; (*b*) the use of ceramic-tipped cutting tools; and (*c*) the use of precision cast milling cutters. In the manufacture of jet engines too, considerable savings appear to be possible in the U.S.A. where substantially higher proportions of scarce alloying elements are in use, as compared with British practice.

We stated earlier that the present situation presented a challenge to those in any way connected with the use of metals. What are we doing to meet it? Problems such as this are not overcome merely by sitting round a conference table and deciding that material *A* shall be replaced by material *B*: to be able to change so easily would be indicative of gross extravagance in the past. One often hears that some system or other has been "tried and found wanting" when in reality it has been tried and found difficult. Maybe it is in that light that we have, in the past, viewed possible changes in material—and rightly so when "difficult" may be translated as "more costly." Circumstances alter cases, however, and when necessity is the driving force, the re-design, testing and investigation work will doubtless be undertaken.

This brings us to an important point referred to by Mr. F. Hudson in his paper to the Institute of Metals Conference, namely, the quality, as distinct from the quantity of metals. If the uniformity and quality of metal products, castings in particular, could be improved, so that a reliable relationship could be established between test bar properties and the properties of the casting, a considerable saving of metal could be achieved by reducing the factor of safety employed. Again, in cases where the basis metal of the alloy is scarce, use of an alloy with higher properties, by reducing the section necessary, might actually prove to have economic advantages, although productivity, as it is affected by manipulation, machining, etc., would have to be watched.

We have heard a lot about secondary metals, recently, and those engaged in scrap recovery have every reason to be proud of the important part they are playing in the national economy. But let us consider the sources of their raw material—scrap. There is undoubtedly an important source in "old scrap," arising from obsolete or broken equipment and machines, and remelting of such material can be nothing but gain to the community. On the other hand there is "new scrap" arising in production. This material has never done a day's work in its life and it behoves everyone, producer and user alike, to see that this source of scrap is no more excessive than necessary, by reducing machining and shearing allowances where possible, and by cutting down the loss due to defective workmanship. Whatever connection we have with metals, whether as producers, fabricators or users, there is probably some step coming within our field of responsibility which, if taken, will lead to an improvement in the supply position—let us not fail.

* Copies may be obtained from the Anglo-American Council on Productivity, 21, Tothill Street, London, S.W.1. (Price 2s. post free).

High-Temperature Embrittlement in Chromium-Iron Alloys Containing 12-16% Chromium

By Helmut Thielsch*

The serious embrittlement which may be shown by ferritic stainless steels on heating at elevated temperatures is discussed. It is shown that grain growth is not responsible and the suggestion is made that the embrittlement may be related to effects caused by the solution of carbide at elevated temperatures. Means whereby the carbide solution may be prevented, or its effects overcome, are indicated.

IN recent years, a considerable number of papers have been published on two phenomena which tend to embrittle chromium-iron alloys containing over 14% chromium. They are known as 885° F. (475° C.) brittleness and sigma-phase embrittlement. The 885° F. (475° C.) brittleness occurs when these steels are heated between 750° and 1,000° F. (400° and 540° C.). Sigma-phase embrittlement, which seems to be somewhat related to 885° F. (475° C.) brittleness, occurs when chromium-iron alloys containing over 17% chromium are exposed for sufficiently long periods of time at temperatures between 950° F. (510° C.) and 1,300°–1,500° F. (705°–815° C.). However, a third type of embrittlement may occur in these alloys about which very little has been written. This embrittlement may be observed in those chromium stainless steels which become fully ferritic at temperatures above approximately 2,100° F. (1,150° C.) and are then cooled in air or by means of a water quench. The effects of this embrittlement are very detrimental. For example, the elongation of embrittled tensile specimens is lowered to a few per cent.

This high-temperature embrittlement has often been observed in castings or welded sections of ferritic chromium-iron alloys in the as-cast or as-welded states.[1] For example, in welded sections in which a single weld bead has been deposited, the embrittlement occurs in the ferritic weld metal and in that part of the adjacent heat-affected zone which has been heated to temperatures above approximately 2,100° F. (1,150° C.).[2] Generally, the resulting brittle failures, which have been noted in a number of commercial installations, have been erroneously ascribed to an excessively large grain size. Actually, since subsequent heat treatments may remove the effects of this embrittlement without affecting the grain size, some other mechanism must be responsible. This mechanism, which seems to be related primarily to the solution of carbides at elevated temperatures, depends also upon the microstructure which the 12–16% chromium-iron alloys exhibit at the elevated temperatures.

Whether or not an alloy is susceptible to the high-temperature embrittlement depends upon the various elements which determine the austenite-ferrite equilibrium at elevated temperatures.

The amount of ferrite and austenite present at elevated temperatures may be estimated from Bain's gamma loop which, for each particular composition, shows how much austenite is likely to form. For commercial, low-carbon, chromium-iron alloys the extent of the gamma loop is shown in Fig. 1.

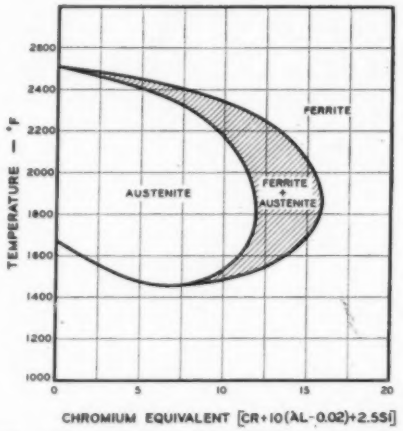


Fig. 1.—The " Gamma Loop " as influenced by chromium, aluminium and silicon in stainless irons containing 0.05% carbon.

In 12% chromium-iron alloys, the gamma loop has its greatest extent at about 1,800° F. (980° C.) which increases to about 1,950° F. (1,065° C.) for alloys containing about 16% chromium. As the alloys are heated to temperatures above these maxima, increasing quantities of austenite are again transformed into (delta) ferrite.

In the steels in which austenite forms at elevated temperatures, the M_s temperature at which the austenite transforms into martensite lies below 900° F. (480° C.) Thus, on quenching or air cooling from temperatures at which austenite has formed, these steels will exhibit a structure consisting primarily of martensite, ferrite, or a mixture of both. The actual amounts depend upon the initial quantity of austenite—i.e., the composition and the temperature of the heat treatment.

To become fully ferritic, the steel has to be furnace cooled very slowly and held above 1,200° F. (650° C.) or, after quenching, has to be soaked thoroughly between 1,300° and 1,500° F. (705° and 815° C.).

Effects of Carbon

Apart from chromium, carbon is the major element affecting the location of the gamma loop. Ordinarily, carbon tends to form the chromium carbides Cr_7C_3 and Cr_4C (also written as $Cr_{23}C_6$). Actually, as Westgren,

* Welding Research Council, formerly, Lukens Steel Company.

1 Thielsch, H., "Physical and Welding Metallurgy of Chromium Stainless Steels," *The Welding Journal*, **30**, *Research Suppl.*, 1951, 209-s to 250-s.
2 Thielsch, H., "Weld Embrittlement in Chromium Stainless Steels," *The Welding Journal*, **29**, *Research Suppl.*, 1950, 126-s to 132-s.
3 Bain, E. C., "The Nature of the Alloys of Iron and Chromium," *Transactions, American Society for Steel Treating*, **9**, 1926, 9-32.

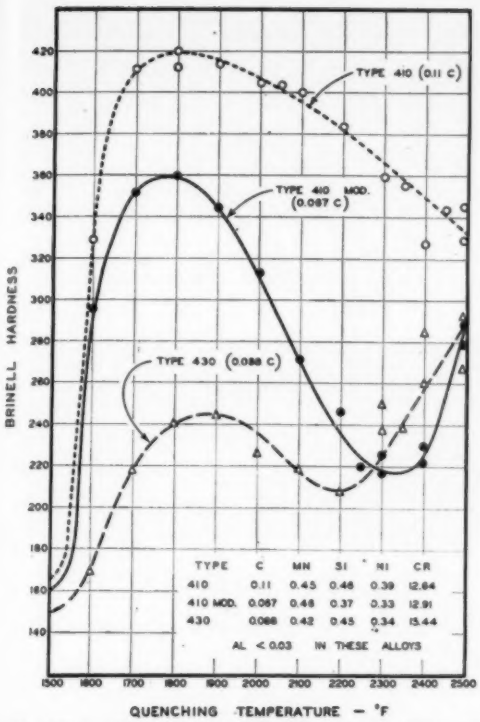

TYPE 410 (0.11 C)
TYPE 410 MOD. (0.097 C)
TYPE 430 (0.088 C)
BRINELL HARDNESS
QUENCHING TEMPERATURE – °F
TYPE C MN SI NI CR
410 0.11 0.45 0.48 0.39 12.84
410 MOD. 0.097 0.48 0.37 0.33 12.91
430 0.088 0.42 0.45 0.34 15.44
AL < 0.03 IN THESE ALLOYS

Fig. 2.—The effects of quenching temperature on the hardness values of typical Type 410 and 430 stainless irons.

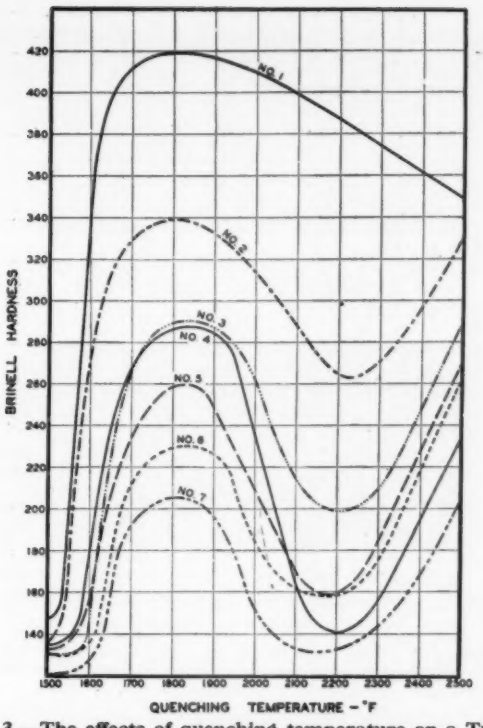


Fig. 3.—The effects of quenching temperature on a Type 410 and various Type 405 stainless irons.

Phragmen and Negresco[4] have shown, some iron may dissolve in these carbides. Thus, the formulæ are also written as $(Cr, Fe)_7C_3$ and $(Cr, Fe)_4C$, respectively.

Although the percentages of iron in the Cr_4C particles may be as high as 40–60%, these carbides usually contain considerably less.[5] The amount of iron in these carbides decreases as the temperature and/or time of precipitation are increased.[5, 6] These variations in the carbide composition and the remaining free carbon and chromium content are likely to cause some variation in the limits of the austenite and austenite-ferrite regions of the gamma loop.

Commercial Alloys

Ordinarily, commercial wrought chromium stainless steels (0·15% max. carbon), which contain up to about 13·5% chromium, such as Type 410, will primarily form austenite at elevated temperatures. Since, on air cooling, this austenite will transform into martensite, these steels are also called martensitic or hardenable stainless steels. By restricting the carbon content to a maximum of 0·08%, these alloys form less austenite at elevated temperatures and are, thus, less hardenable on cooling. The latter more restricted compositions are also known as *modified* Type 410 alloys.

Aluminium is one of the most effective elements which may be used to stabilize ferrite.[1] Thus, when from 0·10–0·30% of aluminium is added to a low-carbon (0·08% max. carbon) 11·5–13·5% chromium stainless steel, the steel will become essentially ferritic—i.e., not hardenable. Such a steel is commercially produced under the A.I.S.I. designation Type 405. 14–18% chromium stainless steels, containing not more than 0·12% carbon, are also essentially ferritic and are produced under the designation Type 430.

Experimental Procedure

Sections from over 100 different plates and sheets from commercial Types 410, 410 *modified*, 405 and 430 stainless steels were studied in this investigation. Tensile-test specimens were heat treated in the form of 1-in. square bars; after quenching, they were machined down to standard 0·505-in. dimensions. A few standard sheet tensile tests were also made on the $\frac{1}{8}$-in. thick sheet specimens to allow comparison between the thin test coupons used for hardness determinations and the heavier bars used for standard 0·505-in. tensile coupons. Charpy keyhole impact specimens were initially milled down to a $\frac{1}{2}$-in. square cross section, and after suitable heat teatments and water quenching, these sections were machined to their standard Charpy dimensions.

Hardness values were generally obtained from thin test coupons measuring approximately $1 \times 1 \times \frac{1}{8}$–$\frac{3}{16}$ in. These were heat treated at various elevated temperatures, water quenched, and then ground to remove the effects of surface oxidation. Rockwell "B" or "C" readings were taken and were then converted to Brinell hardness numbers. For the same heating and quenching treatments, the hardness values of the small test coupons were identical with check determinations on the impact and on the tensile specimens.

4 Westgren, A., Phragmen, G. and Negresco, T., "On the Structure of the Iron-chromium-carbon System," *Journal Iron and Steel Institute*, **117**, 1928, 383–400.
5 Hendremont, E., Koch, W. and Wiester, H. J., "Beitrag zur Kenntnis der Umwandlungsvorgänge in Chrom- und Manganstählen," *Archiv für das Eisenhüttenwesen*, **18**, 1945, 147–154.
6 Crafts, W. and Ofenhauer, C. M., "Carbides in Low-chromium Steel," *Transactions, American Institute of Mining and Metallurgical Engineers*, 1943, 361–373.

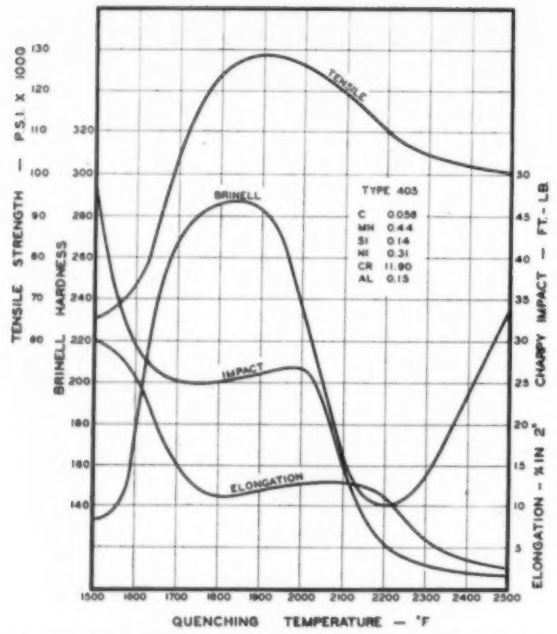


Fig. 4.—Effects of quenching temperature on the mechanical properties of a Type 405 stainless iron.

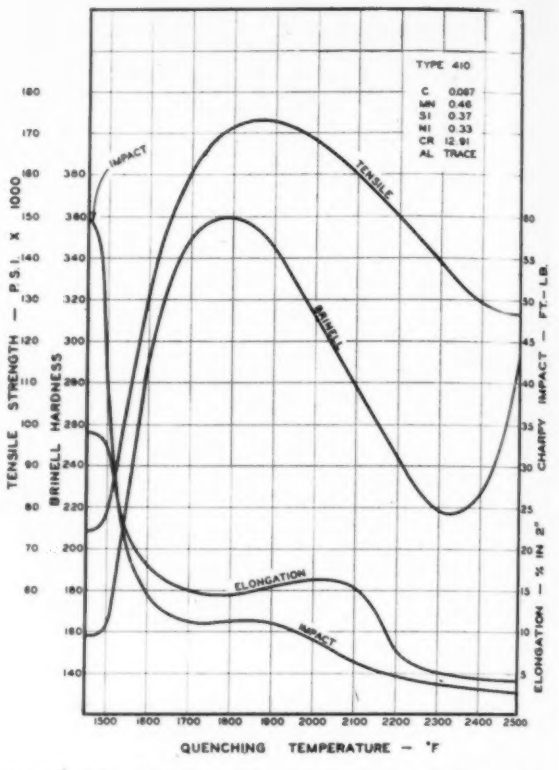


Fig. 5.—Effects of quenching temperature on the mechanical properties of a modified Type 410 stainless iron.

The heat-treatments themselves were conducted in a Globar furnace at temperatures between 1,500° and 2,500° F. (815° and 1,370° C.). The various types of specimen were heated for 20 minutes, and a rapid water quench was obtained by placing the quench tank immediately under the furnace door ; the test specimens were dropped into the tank and agitated.

Hardness Determinations

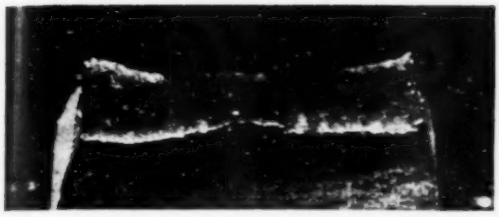
In these 12–16% chromium stainless steels, chromium, carbon and aluminium are the most important elements which determine the structure and, consequently, the mechanical properties. For chromium and carbon, the quench-hardness values are plotted in Fig. 2. The effects of carbon and aluminium are evident from Fig. 3. The analyses of the alloys shown in Fig. 3 are reported in Table I.

TABLE I.—ANALYSES OF QUENCHED ALLOYS PLOTTED IN FIG. 3.

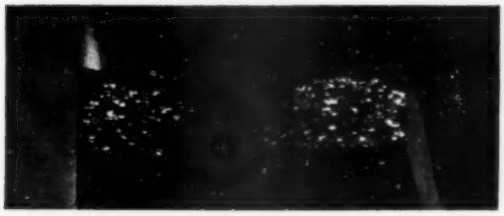
Alloy No.	A.I.S.I. Type	C %	Mn %	Si %	Ni %	Cr %	Al %
1	410	0·110	0·45	0·46	0·39	12·64	0·03
2	405	0·068	0·44	0·15	0·34	12·60	0·15
3	405	0·070	0·27	0·44	0·32	13·10	0·17
4	405	0·056	0·44	0·14	0·31	11·80	0·15
5	405	0·038	0·48	0·39	0·12	12·55	0·15
6	405	0·045	0·40	0·42	0·23	12·17	0·17
7	405	0·051	0·40	0·27	0·31	12·23	0·26

A peak in hardness values occurs between 1,800° and 1,900° F. (980° and 1,040° C.). This, of course, corresponds to the austenite range of the gamma loop, which, for alloys of this series, has its greatest extent at these same temperatures. The curves in Fig. 2 and 3 demonstrate how carbon will increase the maximum martensitic hardness values by widening the gamma loop at 1,800° F. (980° C.), whereas aluminium and chromium will counteract its effects and tend to stabilize ferrite. All of the Type 405 stainless alloys contained between 11·9 and 13·1% chromium. As would be expected from the composition, Alloy No. 2, containing only 0·15% silicon, exhibits relatively high quench-hardness characteristics as compared with the majority of alloys containing between 0·30 and 0·50% silicon. The low content of silicon, which, as a ferrite former, is in these alloys about two to three times as effective as chromium, and about one-fifth as effective as aluminium, caused Alloy No. 2 to exhibit higher hardenability on quenching from 1,800° F. (980° C.).

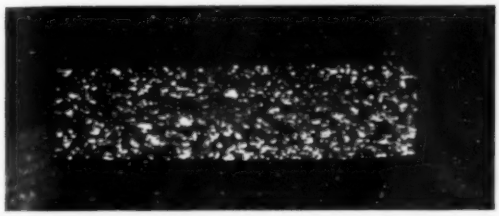
At about 2,200° F. (1,205° C.), the quench-hardness curves of the Type 405 and 430 stainless steels will assume minimum values which will increase again after quenching from higher temperatures. *Modified* Type 410 grades, containing less than 0·08% carbon, will exhibit a similar trend. However, it should be noted from Fig. 2 that, in the *modified* Type 410 alloy, the inversion temperature was at 2,300° F. (1,260° C.), and, in many alloys, it will be even higher if the carbon content is greater. However, slight variations may also be due to changes in chromium or silicon content. Type 410 specimens, containing more than 0·08% carbon, do not seem to experience this minimum in hardness values. This, at least, is true at quenching temperatures as high as 2,500° F. (1,370° C.). As will be subsequently shown, the absence of a minimum in hardness values of the higher carbon Type 410 alloys is due to the fact that not all of the austenite dissolves, even up to 2,500° F (1,370° C.).



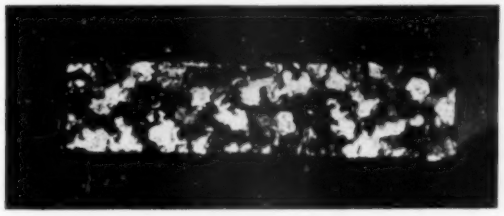
6 (*a*) Quenched from 1,600° F. (870° C.) ; Brinell hardness 140 ; 25% elongation ; shear fracture.



6 (*b*) Quenched from 1,800° F. (980° C.) ; Brinell hardness 287 ; 11% elongation ; $\frac{1}{3}$ shear, $\frac{2}{3}$ cleavage fracture.



6 (*c*) Quenched from 2,200° F. (1,205° C.) ; Brinell hardness 198 ; 5% elongation ; cleavage fracture.



6 (*d*) Quenched from 2,500° F. (1,370° C.) ; Brinell hardness 288 ; 1% elongation ; cleavage fracture.

Fig. 6.—Effect of quenching temperature on the macrostructures of fractured Type 405 tension specimens. (C—0.07 ; Mn—0.27 ; Si—0.44 ; Ni—0.32 ; Cr—13.10 ; Al—0.17). All × 5.

Mechanical Properties

Elongation and Charpy keyhole impact values are also adversely affected when the specimens are quenched from temperatures above 2,200° F. (1,205° C.). This is evident from Figs. 4 and 5 which, for a Type 405 and a *modified* Type 410 stainless iron, show a sharp drop in these properties. The tensile strength, generally does not appear to experience a sudden change. Instead, the values seem to decrease from a maximum which occurs in specimens quenched from about 1,800° F. (980° C.). Only a slight levelling off in the slope of the curve can be observed for quenching temperatures above 2,200° F. (1,205° C.). Similar results are obtained with Type 430 stainless irons.

Because of considerable scatter in tensile test values of the tensile specimens quenched from above 2,200° F. (1,205° C.) it is somewhat difficult to evaluate accurately the effects of the high temperature embrittlement on the tensile strength. Nevertheless, it is apparent that the tensile bars quenched from above 2,200° F. (1,205° C.) exhibit tensile values considerably higher than the specimens quenched from 1,500° F. (815° C.).

The drop in impact toughness and ductility shows much more clearly than the tensile data that the simultaneous increase in hardness values, caused by quenching the steels from 2,200°–2,400° F. (1,205°–1,315° C.), may be associated with an embrittlement.

The examination of tensile and impact fractures also reveals the change from ductile to brittle behaviour. This is shown in Fig. 6 in a series of tensile fractures of a Type 405 alloy. The mode of fracture changes from shear on quenching from 1,600° F. (870° C.) to cleavage at 2,200° F. (1,205° C.).

Microstructures

Study of the microstructure indicates that the high-temperature embrittlement occurs in conjunction with a severe grain growth. This is evident from Fig. 7, which shows characteristic photomicrographs of a typical series of such alloys. The corresponding hardness values of each specimen are also given. The structures are of specimens exposed at 1,600°, 1,800°, 2,200° and 2,500° F. (870°, 980°, 1,205° and 1,370° C.) for 20 minutes and then quenched into water. Generally, they show a matrix of martensite and ferrite in addition to carbides and other finely dispersed particles.

On quenching from 1,600° F. (870° C.), the alloys will primarily contain ferrite and dispersed carbides. Only the higher carbon Type 410 stainless steels will exhibit some martensite, because carbon tends to decrease somewhat the lower temperature limit of the gamma loop. The austenite, which forms in these alloys above about 1,600° F. (870° C.), appears as martensite in the quenched specimens.

Alloys quenched from about 1,800° F. (980° C.) will contain a maximum amount of martensite which decreases again with higher quenching temperatures. In this range, the amount of martensite formed is the main factor which determines the hardness values of the quenched specimens. However, this does not hold true when the temperatures at which severe grain growth occurs are reached. At these temperatures, the hardness reading is no longer an absolute indication of the microstructure and, of course, the other mechanical properties. Only the relatively high-carbon Type 410 alloy does not exhibit the excessive grain growth shown by the other three alloys (Fig. 7). Consequently, the hardness curve of this steel does not show a sudden change.

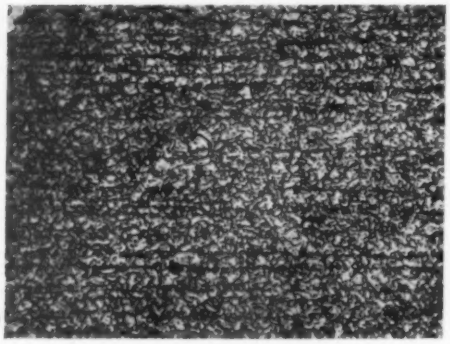
The grain size of the *modified* Type 410 specimen after quenching from 2,500° F. (1,370° C.), which is apparent from Fig. 7 h, is the same as that of the correspondingly treated Type 430 specimen shown in Fig. 7 l. The martensite present in Fig. 7 h was transformed from austenite which, earlier, had formed from (delta) ferrite on quenching through the gamma loop.

Heated 20 minutes at 1,600° F. (870° C.) and water quenched.

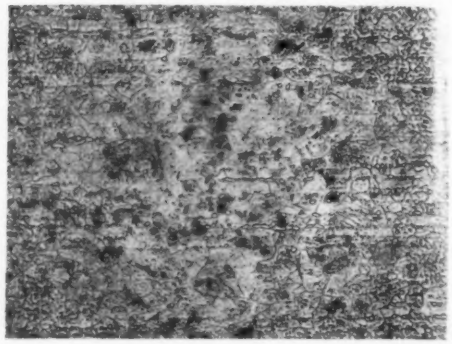
Heated 20 minutes at 1,800° F. (980° C.) and water quenched.

Type 410

C	0·11
Mn	0·45
Si	0·46
Ni	0·39
Cr	12·64
Al	0·03



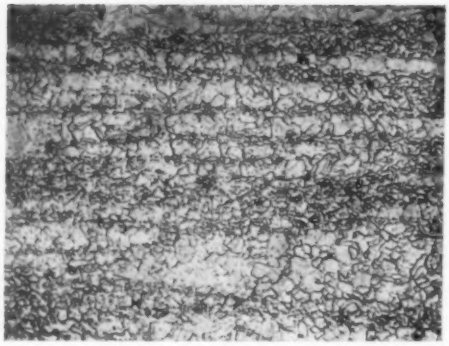
(a)



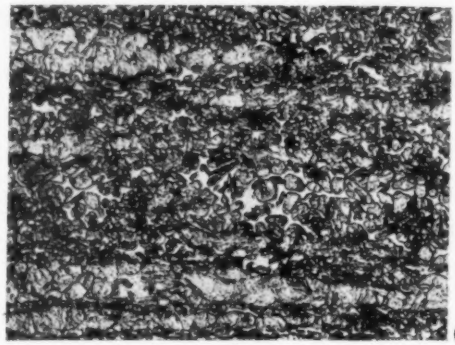
(b)

Type 410 (modified)

C	0·067
Mn	0·46
Si	0·37
Ni	0·33
Cr	12·91
Al	0·03



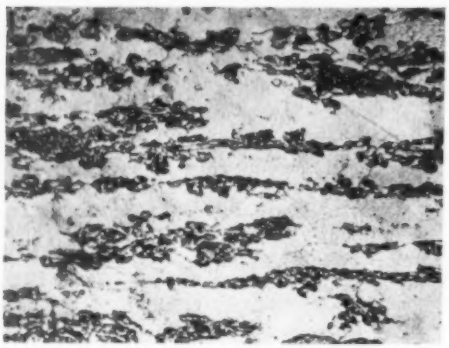
(e)



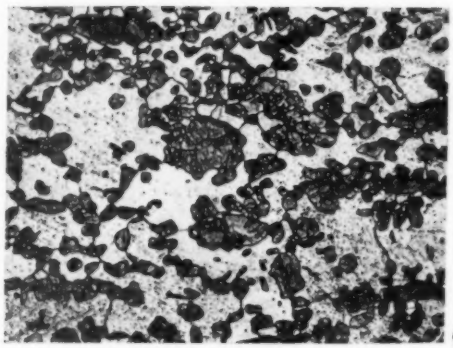
(f)

Type 430

C	0·088
Mn	0·42
Si	0·45
Ni	0·34
Cr	15·44
Al	0·03



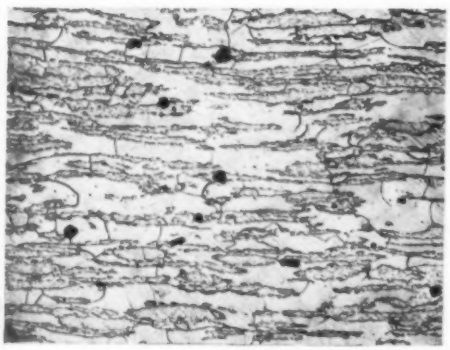
(i)



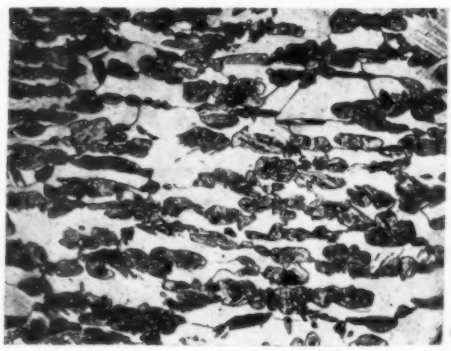
(j)

Type 405

C	0·051
Mn	0·40
Si	0·27
Ni	0·31
Cr	12·23
Al	0·26



(m)

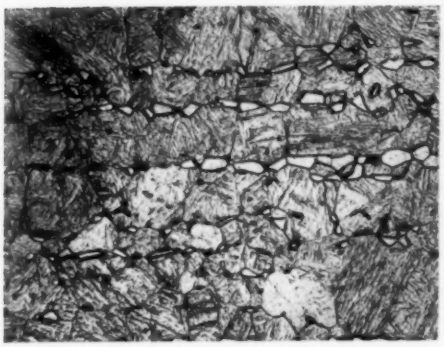


(n)

Fig. 7.—Effects of quenching temperature on the microstructure and hardness of various

Heated 20 minutes at 2,200° F. (1,205° C.) and water quenched.

Heated 20 minutes at 2,500° F. (1,370° C.) and water quenched.

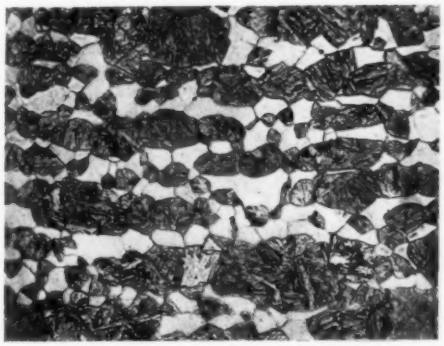


(c)

(d)

Brinell Hardness

(a) 328
(b) 420
(c) 384
(d) 328–346

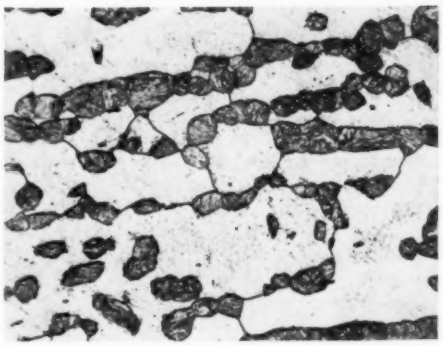


(g)

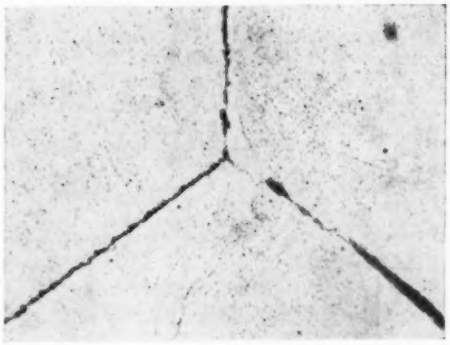
(h)

Brinell Hardness

(e) 296
(f) 359
(g) 246
(h) 278–288



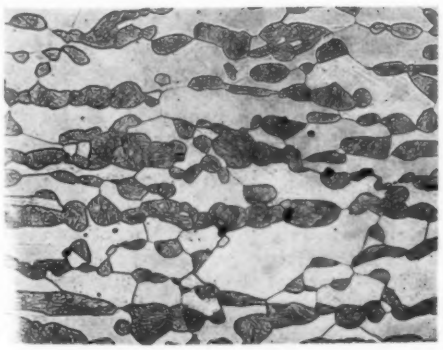
(k)



(l)

Brinell Hardness

(i) 170
(j) 241
(k) 208
(l) 264–292



(c)

(p)

Brinell Hardness

(m) 125
(n) 205
(o) 133
(p) 200–213

stainless irons. All taken at a magnification of × 200 and reduced ⅓ linear in reproduction.

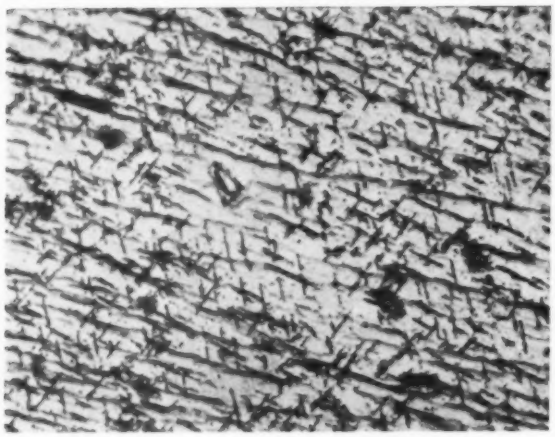


Fig. 8.—Widmanstätten carbide patterns produced by annealing for 1 hour at 1,350° F. (730° C.) of Type 430 stainless iron quenched from 2,500° F. (1,370° C.) (C—0.088; Mn—0.42; Si—0.45; Ni—0.34; Cr—15.44; Al—0.03). Taken at a magnification of × 500 and reduced $\frac{7}{8}$ linear in reproduction.

Removal of the Effects of the Embrittlement

Annealing for 1 hour at temperatures between about 1,200° and 1,450° F. (650° and 790° C.) removes the embrittlement and reduces hardness to normal values.* This is apparent from Table II in which are listed the mechanical properties of a ferritic Type 405 stainless steel (the same as is shown in Fig. 4) after water quenching from 2,500° F. (1,370° C.) and after a subsequent annealing treatment for 1 hour at 1,350° F. (730° C.). Structurally the recovery in mechanical properties may primarily be associated with the reprecipitation of chromium carbides. These particles precipitate in a Widmanstätten type of pattern such as is shown in Fig. 8 for a deeply etched Type 430 stainless steel containing 15·44% chromium. The grain size was not changed by the annealing treatment.

TABLE II.—EFFECTS OF ANNEALING FOR 1 HOUR AT 1,350° F. (730° C.) ON THE MECHANICAL PROPERTIES OF A SPECIMEN PREVIOUSLY EMBRITTLED BY HEATING FOR 20 MINUTES AT 2,500° F. (1,370° C.).

Treatment	Brinell Hardness	Tensile Strength lb./sq. in.	Elongation % in 2 in.	Charpy Impact ft.-lb.
Water quenched from 2,500° F. (1,370° C.)	235	102,000	3	2
Water quenched from 2,500° F. (1,370° C.) and annealed 1 hour at 1,350° F. (730° C.)	138	66,000	27	43

Discussion

It is now apparent that the embrittlement occurs only when these chromium-iron alloys have become fully ferritic at elevated temperatures and when a substantial quantity of the carbides has gone into solution in the ferrite matrix. Commercial ferritic chromium stainless steels containing as little as 0·035% carbon have shown susceptibility to the embrittlement. On the other hand, a vacuum-melted ferritic 12% chromium steel containing 0·004% carbon and 0·004% nitrogen was not embrittled after water quenching from 2,400° F. (1,315° C.).[7]

The actual mechanism by which the "free" carbon causes the embrittlement requires further experimental study. The fact that annealing of embrittled steels at intermediate temperatures removes the embrittlement by reprecipitating the chromium carbides in a Widmanstätten pattern within the ferrite grains may give support to the *segregation* or *coherent state* hypotheses. Thus, it may be postulated that the embrittlement might be caused by segregations of carbon atoms arrayed relative to the lattice pattern of the ferrite matrix. Because such segregates are unlikely to occur above 2,200° F. (1,205° C.) it may be that they are produced during air cooling or water quenching when, in these steels, these rapid cooling rates prohibit carbide precipitation. However, another hypothesis should also be considered.[8] It is based also on the existence of regions relatively high in carbon which cause small amounts of austenite to be formed in these regions at elevated temperatures. During subsequent cooling these austenitic regions would transform to martensite which results in planes of embrittlement. On annealing between 1,200° and 1,450° F. (650° and 790° C.) the martensite will be tempered and carbides will precipitate in these same regions. These two hypotheses are the subject of a separate investigation.

Conclusions

In ferritic stainless steels, the high-temperature embrittlement may be related to effects caused by carbide solution at elevated temperatures. Grain growth itself, as is often erroneously assumed, is not responsible for the embrittlement. In these steels, the prevention of carbide solution is highly desirable, primarily because of the resulting reduction in ductility and toughness, which is generally extremely severe. The detrimental effects caused by carbide solution can be removed by heat treatments in the intermediate temperature range which will cause reprecipitation of the carbides. Other methods comprise the adjustment of the composition to allow the retention of some austenite at the temperatures at which the carbides go into solution, or the addition of carbide stabilizers which raise the temperatures at which the carbide particles become unstable and go into solution.

Acknowledgment

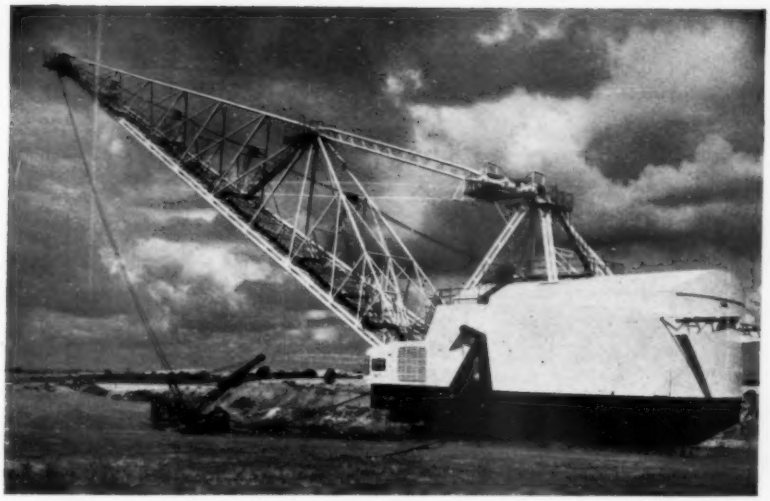
The author wishes to express his appreciation to the Lukens Steel Company for their permission to publish the experimental data which were the basis of this paper. He is also extremely grateful to Mr. T. T. Watson, Lukens Steel Company; Dr. C. H. Samans, Standard Oil Company of Indiana; Mr. F. B. Foley, The International Nickel Company; Mr. M. A. Scheil, A. O. Smith Corporation; and Mr. W. O. Binder, Union Carbide and Carbon Research Laboratories for their many constructive criticisms and suggestions. Mr. R. Rote, Lukens Steel Company, assisted in the preparation of the microspecimens and the photomicrographs.

* Annealing at temperatures somewhat lower than 1,200° F. (650° C.) may also cause removal of the embrittlement. However, in order to remove the embrittlement longer periods are necessary which increase the lower the annealing temperature. Below 1,000° F. (540° C.) the embrittlement cannot be removed in practical heat-treating periods.

7 Binder, W. O., Private Communication, Union Carbide and Carbon Research Laboratories, Niagara Falls, N.Y.

8 Samans, C. H., Private Communication, Standard Oil Company of Indiana, Chicago, Illinois.

World's Largest Walking Dragline



ALTHOUGH there is evidence that ironstone was being worked at Corby in the time of the Romans, the restrictions on charcoal burning introduced in Elizabeth's reign led to the cessation of iron production in Northants, and it was not until the coming of the railway that the extensiveness of this orefield was again appreciated. Railway cuttings exposed the ironstone beds, and it is only since 1850 that the present developments have taken place.

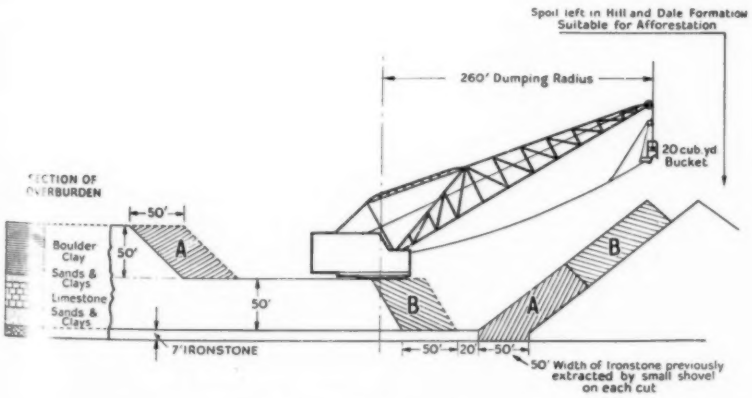
The Northants sand ironstone bed extends from Central Lincolnshire across Leicestershire, Rutland and Northants and is a sedimentary deposit running horizontally under an overburden of soil, clay and limestone. The ironstone may be just below the surface or at much greater depths; the maximum depth at which it has so far been found by drilling is 216 ft.

As the ore bed is only some 7 ft. thick, and lower in iron content than much of the imported ore, it is essential that it should be worked as cheaply as possible. To date opencast quarrying has provided the answer, but at some time in the future it is likely that it will be necessary to resort to underground mining. The principle of opencast mining is similar to double spit digging. A trench is first excavated until the ironstone is reached. When the ironstone has been removed from the foot of the trench, the next section of overburden is stripped and deposited in the original trench and a further section of ironstone is thus exposed. In successful opencast quarrying, a vital factor is the cost of removing the overburden, and as the depth of the latter increases, the cost of stripping becomes of paramount importance. On the other hand, it must be remembered that the alternative—underground mining—calls for ten times as many men and suffers from the disadvantage that it is not possible to remove the whole of the ironstone because of the necessity of maintaining a safe roof.

The Problem of Deep Overburden

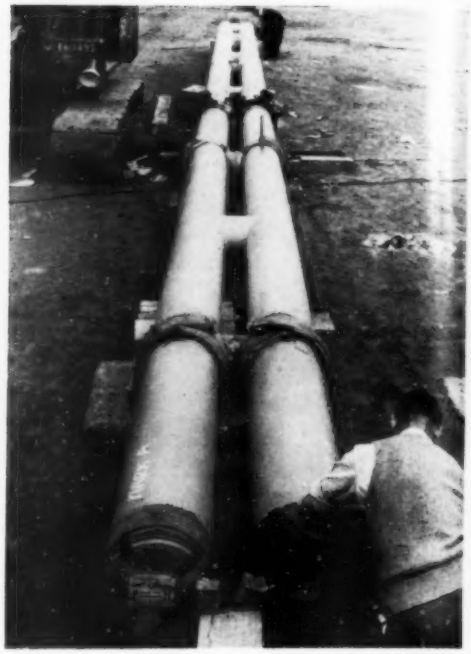
When the Corby works of Stewarts and Lloyds was built in the 1930's, a number of Rapier electric shovels, capable of stripping the overburden down to a depth of 55 ft. in one operation, were installed in the ironstone quarries. Later, as the depth of the overburden increased, the shovels could not operate economically because, digging upwards from below, the height to which they can work is necessarily limited. On the other hand, a dragline scoops up from above, and is therefore capable of removing the overburden, in one operation, to a greater depth than is possible with a shovel. In deep quarrying, the distance at which the excavated spoil can be dumped from the working position of the excavator depends on the dumping radius, and thus on the jib length.

There are now, in present quarry areas, overburden depths up to 100 ft., and its economical removal presents a problem of major importance. In 1950, Stewarts and Lloyds installed in one of their quarries a large walking dragline of American make with a 215 ft. jib to strip the overburden down to a depth of 75 ft. Even this huge machine,



Diagrammatic sketch showing W.1400 operating.

Above.—The first stage in construction of the jib. The wood and concrete blocks are placed to receive the main compression members with one heel socket in position.



Right.—Two 40 ft. lengths of the twin boom compression member on site being lined up for butt-welding.

although the largest in existence, would not be able to deal with 100 ft. of overburden such as now exists in Stewarts and Lloyds' Prior Hall Quarry. This quarry was opened in 1941 and at the extraction rate of 400,000 tons/annum required in the future, it is estimated that the remaining life of the quarry will be 33 years.

From the outset it was realised that a solution would have to be found to the problem of removing this 100 ft. overburden. Various possible methods were considered by the Company, and visits were paid to the United States and to Germany to study their systems of opencast working, but none of the existing machines proved suitable. It was finally decided that a huge walking dragline, bigger than anything of its kind yet evolved, would be the only way of dealing with the problem of deep overburden, and Ransomes and Rapier, Ltd., were asked to design and build a machine to meet the Company's requirements. Designs for what is now known as the W.1400 walking dragline were submitted and the order placed in 1947.

The Solution—W.1400

This enormous machine, which was put into operation recently, weighs 1,600 tons and in its working position, the head of the jib, at 175 ft. above the ground, is 5 ft. higher than Nelson's column. The dumping radius is 260 ft., and when slewing the head of the jib approaches a speed of 23 m.p.h. The bucket, which weighs 22 tons, digs some 27 tons at a fill, the time cycle of bucket filling, swinging to discharge point, emptying, and returning to the digging position, is about 60 seconds, which means that the W.1400 can dig and dump its own weight of 1,600 tons every hour it is working. It carries a crew of two, a driver and an engineer.

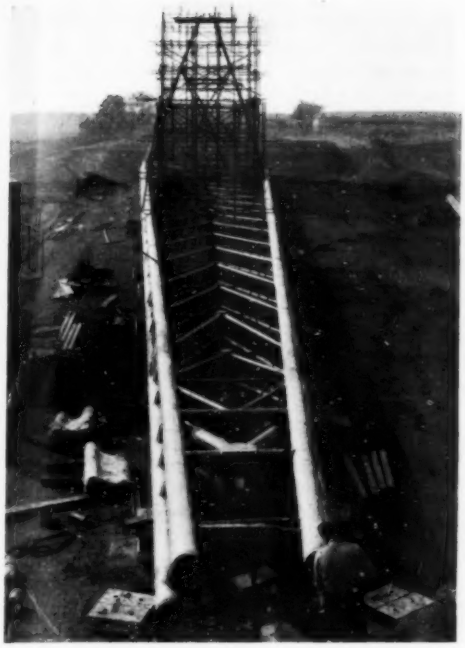
The base structure, or "tub," on which it stands is 48 ft. in diameter, 4 ft. high and weighs 227 tons. On top of the tub is the roller path on which the 1,400-ton superstructure revolves. The cab was designed as a cantilever unit and covers an area greater than two single tennis courts, while the roof is 45 ft. above the ground. Inside the cab there are two decks, the lower deck being divided into three air-conditioned compartments.

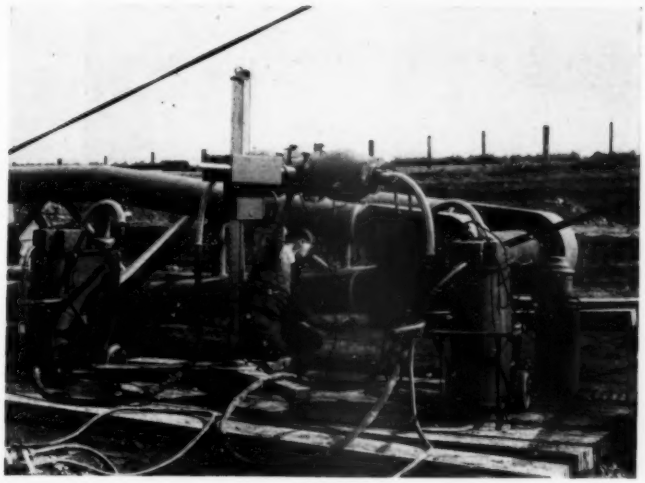
The machine is electrically driven, power at 6,600 volts being taken in through two high tension cables which enter the tub through two oval openings near the base. Transference of power from the centre post to the main motors on the upper deck of the cab is effected by collector rings and brushes. The two main synchronous A.C. motors each drive three generators which supply power to the 225 h.p. D.C. driving motors. There are 14 of these—all interchangeable—4 operating the drag, 4 the hoist, 2 the slewing and 4 the walking mechanism.

The bucket—which will comfortably contain a modern saloon car—weighs 22 tons and is fitted with seven detachable teeth. In operation, the empty bucket is lowered to the ground and drawn towards the machine by the two 6½ in. circumference drag ropes until it is full. The two 7 in. hoist ropes then lift it, the jib slews and, at the appropriate moment, the drag ropes are paid out, the bucket tips and the load is discharged.

The Great Jib

Perhaps the most interesting feature of the W.1400 is the jib, which is a welded triangulated tubular cantilever structure in high tensile steel. Up to 1947, the year in which the design work started, the largest tubular jib in existence was only about 30 ft. long, although in that year a 113 ft. jib was built of tubular construction. It will be appreciated, therefore, that a tubular jib 282 ft. in length was considerably in advance of anything then in existence. The design was evolved by Tubewrights, Ltd., a subsidiary of Stewarts and Lloyds, in collaboration with Ransomes and Rapier, Ltd., who had, of course, the overall responsibility.





Above.—Preparing to X-ray a weld on the suspension member. All the main welded joints were radiographed by X-rays or gamma rays.

Left.—Main compression members with lattice arrangement before erecting the main tension member and showing the thrust block in position before aligning with the nose block.

The main compression and tension boom members were designed as twin tubes with welded distance pieces. Two main compression members run from the heel pieces to the head of the jib, and the main tension member from the head to the apex, when it bifurcates into a fish tail arrangement from the apex to the heel pieces. The main compression boom members taper from 16 in. in diameter, under the apex, to 10 in. at the head and 15 in. at the heels. The main tension boom tapers from 15 in. at the apex to 5½ in. at the head. This twin tube system was also used in planning the 'A' frame, the front and back legs being built into the machine housing, while the top forms an anchorage which, through the suspension member holds the jib in the air.

The suspension member, which is connected between the top of the "A" frame and the apex of the jib, also controls the angle at which the jib works. The more usual method of controlling this angle (a possible variation of 5° is normal in this type of machine) is by a series of wire ropes, but in view of the difficulty of ensuring equal sharing of the load by all the ropes, it was decided to make a complete departure from the normal practice and use a rigid box beam arrangement of four 10-in. tubes. The variation in operating angle is effected by an easily altered link system which also enables the suspension member to cushion any shock caused by the sudden release of the load on the jib, and to prevent compressive stress in the upper boom tension member, due to sudden freeing of the bucket after it has become snagged.

The design having been fixed, there remained the selection of materials and methods of construction to be decided. Tubes, plates and forgings were required in a high tensile steel suitable for welding with a minimum amount of preheating or post-heating, and the choice of material was governed also by the fact that a high proportion of the welding would have to be done on site, where the exposed position would present difficulty in providing protection from adverse weather conditions.

After considerable research and experiment, a special steel was evolved by Stewarts and Lloyds' Department of Research and Technical Development. This was a high tensile chromium-molybdenum fine grain steel, aluminium killed. For successful welding under the particular conditions specified, a fine grain steel was essential and the McQuaid-Ehn grain size was specified as grade 6 or finer. This new steel was designed to give better tensile properties, a high yield point and a less tendency to harden in the heat-affected zone. With the preheating temperature of 160° C. selected, the hardness in this region is less than 300 V.P.N.

Some 18,000 electrodes were used by the two welders who carried out the whole of the welding, and as the joints were of many types, including butt and branch welds of varying angles, and in some cases involving several tubes of different sizes meeting at the same point, it will be appreciated that a great deal of research and exhaustive tests had to be carried out in order to arrive at the most satisfactory welding technique. These included tensile, bending and vibration tests, micro-examination and hardness testing. It was found that preheating to 160° C. was necessary, but that post-heating after welding could be safely omitted. Under the site conditions anticipated, asbestos blanket would have to be placed round the weld to retain the preheat and also to prevent accidental striking of the arc on the adjacent tubes, which would cause local hardening.

The tubes used in the construction of the jib were divided into three categories: (*a*) Main compression and tension members; (*b*) Main members for the 'A' frame and subsidiary bracing members; (*c*) Lattice bracing members. Category (*a*) tubes were seamless, rolled in a pilger mill at Stewarts and Lloyds' Bromford Works, cold-drawn at the Chesterfield Tube Company's Works

The tub assembled at Ransomes and Rapier's Works, showing the roller path and rotate rack.

and then normalised at the Bromford Works. Category (*b*) tubes were hot-finished seamless tubes made at Bromford by the pilger process. The lattice bracing members were made at Corby by the continuous weld process from Bessemer steel.

Inspection and examination took place at each stage of fabrication, and a length was cut from every Category (*a*) and (*b*) tube for testing. A particularly impressive test concerned two pieces of 15 in. dia. tube, butt welded together and pulled in Dorman Long's 1,250-ton tensile machine. Failure occurred at 844 tons against a calculated tube strength of 828 tons.

At the points of hinging and loading, the tubes are welded to steel forgings. The latter were forged from 20-ton ingots in a 2,000-ton hydraulic press by the Parkhead Works of William Beardmore & Co., Ltd., and the squared blocks thus prepared were roughly flame cut to shape by nozzles specially developed by the British Oxygen Company to deal with steel of thicknesses up to 48 in. The forgings were then normalised and machined. Tubular stubs were welded to the forgings at the works under preheat conditions, the main members being welded to the stubs on site.

Several problems had to be overcome in the construction of such a large structure on site. Starting from the heel pieces, the jib was constructed 17 ft. in advance of the frame position of the heel piece sockets on the deck of the machine. When completed it was moved back on a bogie located at the point of balance into the heels engaged in the sockets.

The main compression and tension boom members were assembled in 40-ft. lengths at the works and butt welded on site. In welding together two of these lengths, the twin butt joints had to be preheated and welded at the same time to avoid movement due to differential expansion and contraction. All the butt welds had backing rings to prevent icicles hanging down towards the centre of the tube, and to improve penetration. With a root gap of $\frac{5}{32}$ in., the joint region was heated to 160° C. and tack welded. "Tempilsticks" were used to check the temperature before the main weld was run, and asbestos blankets helped to maintain the preheat and also assisted slow cooling after welding.

As the site was so exposed and some of the welds took a long time to complete, it was necessary to provide adequate protection for all cutting and welding positions in the form of tubular shelters covered with tarpaulin.

The welding technique to be adopted was clearly laid down and a record was kept of every weld made on the job and of the fitter who did the assembly. Each weld was examined visually and all the more important ones were subjected to X-ray or gamma-ray inspection.

The Walking Mechanism

When it is necessary for the W.1400 to change its position in the quarry, the walking mechanism is put into operation and the huge machine moves slowly along, covering about 200 yds. an hour in steps of nearly 7 ft. On either side of the main superstructure are the great walking shoes, each 48 ft. × 9½ ft. and weighing 56 tons. When at rest, the shoes are parallel to the ground and about 2 ft. above it. For walking, an eccentric causes the shoes to move backwards and down, until the pressure of the shoes on the ground causes the tub to lift at the rear. The 'lift' at the shoes is behind the centre of gravity so during each step the rear of the tub rises slowly until it is about 2 ft. off the ground. As the eccentric movement continues, the tub is dragged backwards almost 7 ft. and then lowered gently back to the horizontal position. The weight lifted on the shoes is some 1,150 tons and the dragged weight at the front about 550 tons.

Because of the dusty nature of the work in dry weather, the cab is air-conditioned. A complete filtering and fan equipment is provided, which supplies 60,000 cu. ft. of filtered air per minute to cool the electrical equipment and to maintain the pressure in the cab slightly above atmospheric in order to prevent ingress of dust.

An up-to-date electrically driven lubricating system is installed which ensures that every point receives the correct amount of lubricant at regular intervals. Another lubricating system maintains an oil spray under pressure to the internal gears in the gear box and an audible warning is given in the driver's cabin if the pressure drops below normal.

As the average working day of the machine is twenty hours, the illumination scheme is of major importance. Externally there is a floodlighting system on the jib which employs ten 1,000-watt and three 500-watt

One of the two sets of cast steel eccentric bosses and walking legs through which the eccentric motion is transmitted to the shoes.

projectors; the driver can thus operate as easily by night as by day. The interior lighting on the upper deck of the cab consists of twelve 300-watt wall lanterns and four 300-watt roof lights. Because of its height above the ground, aircraft warning lights are fitted to the head of the jib.

Identical dual control cabins are arranged one on either side of the machine, separate from the machine and placed well forward to give the operator a clear view down the quarry. The machine can be controlled from either cabin according to the operating conditions. In front of the comfortable driving seat are two foot-operated pedals for slewing to right or left, and on either side of the seat are two hand control levers for the hoist and drag. On the right arm of the seat are the "on-off" switches for the hoist, drag, slew and walk holding brakes, and on the left arm, the switch for the aircraft warning beacon. An intercommunication telephone system is in operation throughout the machine and the cabins can be heated or cooled as desired.

Metallurgical Considerations in the Use of Aluminium for Cable Sheathing—II

By A. Latin, Ph.D., M.Eng.
British Insulated Callender's Cables, Ltd.

A number of interesting problems have arisen in the development of aluminium sheathing for electric cables, and in this article the author discusses a number of metallurgical factors involved, dealing in this issue with the properties of drawn and extruded tube, corrosion and protection, and jointing.

The Properties of Extruded and Drawn Tube

Aluminium tubing as at present used for sheathing is essentially in the extruded and cold-drawn condition. Properties of such tubing relevant to its present application are:

(*a*) Its structure, in particular the presence of any weaknesses, including effects of stop marks, billet-joins, etc.
(*b*) Mechanical properties, which depend upon its "innate" properties and the degree of work-hardening resulting from the sinking (dieing-down) process.
(*c*) Ease of handling from the point of view of such properties as bending and springiness.
(*d*) Resistance to internal pressure, with particular application to pressure cable use.
(*e*) Resistance to corrosion, which will be dealt with in a separate section.

Structure

The structure of the so-called seamless extruded tubing used reflects the fact that it is extruded by the porthole die method so that "seams" or extrusion welds may be present, as described above. These seams are of little moment in good quality tubing extruded from a single billet. Frequently they cannot be seen even with the most careful metallographic examination. Fig. 8 shows a section of an aluminium tube which has four seam positions. The seams are usually less marked than this, and should not constitute a serious source of weakness. The following are typical tensile tests results on specimens taken longitudinally and circumferentially from tubing, the latter specimens containing a seam position across the centre.

There is little effect at the seam.

Sample	Tensile Strength tons/sq.in.	0·5% Proof Stress tons/sq.in.	Elongation %
Longitudinal	4·94	4·33	35
Circumferential	5·24	4·24	32·5

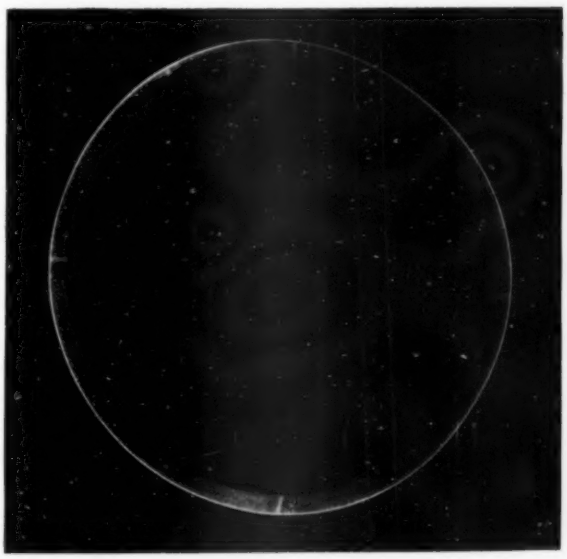


Fig. 8.—Seams in extruded aluminium tube.

Under some conditions, however, weakness can occur in analogy to similar effects with lead. Under slow creep conditions, for example, failure can occur quite sharply at seam positions present along the tube or across the strip.

Another sort of failure at a seam is shown in Fig. 9. This is from a piece of tubing which has been bent to produce a severe buckle, and the brittle behaviour of the seam at this point is clearly demonstrated.

Fig. 10 shows still another effect at a seam. It is of the surface of a tube which has been etched to show the structure, and the straight line down the centre is the seam line. The arrow points to a minute pinhole which developed in this position under the prolonged application of pressure.

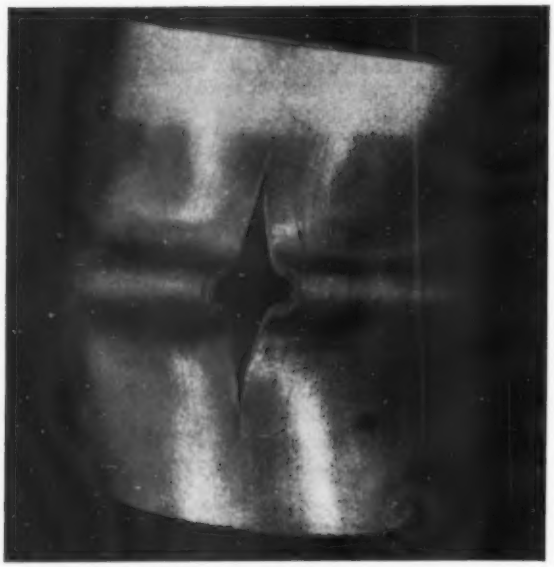


Fig. 9.—Failure in seam position at buckle.

Still another way in which seam weakness can reveal itself is shown in Fig. 11. This is from a tube which has been undergoing corrosion in 3% sodium chloride solution. Attack is most severe at the water line as can be seen (this is a photograph of the surface of the tube), and at this point the short dark line shows a portion of the seam which has corroded through.

It must be emphasised that, with good quality tubing extruded from single billets, these seam effects should not be of a serious nature. The effects may be enhanced when extrusion is carried out from a series of billets, even if otherwise sound billet joining is obtained. One of the problems of billet joining is, in effect, to eliminate any special seam or weld weaknesses resulting from the combined effect of billet successions and porthole dies.

Another feature which is present in tubing and can have serious effects is the stop-mark. Stop-marks are present also in lead sheathing. They take the form of circumferential lines, marked to a greater or lesser degree, around the tubing. These lines are produced at the die of the press during stoppage for re-charging or other reasons. With best practice their presence should not be serious. Weaknesses can occur, however, aggravated by the occurrence of grain growth in the tubing near to the die subjected to the heat of the press during the re-charging, etc. period. There can also occur what amounts to a sort of "notch effect" at stop marks, leading to trouble during bending owing to the formation of a "kink" at this region.

Mechanical Properties

A comparison of the mechanical properties of aluminium and lead has been given above; the former is much superior in tensile strength, fatigue strength and creep resistance. The only point which need be dealt with here is the effect of the drawing-down process on these properties. The effect is shown by some typical results in the following table, which also compares circumferential and longitudinal values. The tests were on specimens taken from tubing reduced in diameter by successive passes through a die.

% Reduction of Tube Diameter	Circumferential Tests			Longitudinal Tests		
	Tensile Strength ton/sq.in.	0·5% Proof Stress ton/sq.in.	Elongation %	Tensile Strength ton/sq.in.	0·5% Proof Stress ton/sq.in.	El... ga... %
None	4·27	3·45	32·5	4·11	3·47	
15	5·08	5·05	10	5·54	5·5	
26	5·13	5·08	10	5·9	5·8	

The quality of aluminium was high; composition 99·7% pure. It will be seen that the chief effect is on the proof stress and elongation.

Handling of Aluminium Sheathed Cable

One of the most important problems in connection with the use of aluminium for sheathing concerns the bending properties. Extensive work has been carried out on the bending of aluminium sheathed cable in order to determine minimum bending radii, etc., but this will not be dealt with here in detail; some of the basic principles concerning tube bending will, however, be outlined. B.S. 480 calls for the ability for lead sheath to bend back and forth, without damage, over a diameter of $12d$ where d=diameter of sheath, for three complete cycles. This is not possible, in the normal manner, with aluminium sheath. The development of corrugation is the chief trouble, and the causes of this corrugation and the reason for the different behaviour from lead are worth enquiring into. The action when freely bending a tube, or when bending it over a drum, etc., has close analogies with the loading of a thin strut under compression, the theory of which is well known to engineers as "Euler's theory." "Elastic instability" occurs under a compressive stress much less than the yield stress of the metal. If the strut is in the form of a tube it will buckle or corrugate if the ratio of the wall thickness to the diameter is small. On bending a tube the inner side is put into strong compression, and behaves very like a sort of "Euler strut"; at a certain radius of bend it will commence to corrugate. The resistance to corrugation depends largely upon the ratio of the wall thickness to diameter of tubing. There is a critical thickness at which the tubing will cease to corrugate on bending; for aluminium it is at least two or three times greater than the wall thicknesses it is practicable to use.

It may be noted that the elastic modulus of aluminium is itself very little affected by purity or by cold-working.

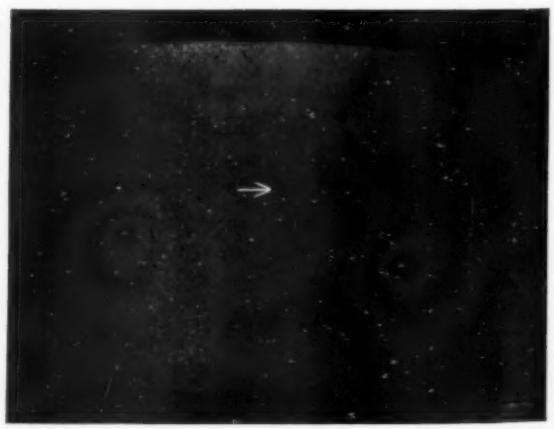


Fig. 10.—Pinhole failure at seam.

so, as far as this factor is concerned, there is no great effect on bending properties. On the other hand the greater softness of superpure aluminium compared with, say, 99·5% pure metal would be expected to result in better bending, etc. properties. This statement is often made in support of the use of very pure aluminium for sheathing, but it is well to realise that it is only true to a limited degree. Another project often proposed is to anneal the sheath, i.e. heat it, and after dieing-down to resoften it. The temperatures required are, however, too high and result in core damage, and, in general, tests have not disclosed any great beneficial effect.

Pressure Resistance

One of the most attractive possibilities in the use of aluminium sheathing is for pressure cable, the need for reinforcement being eliminated owing to the high strength and creep-resistance of aluminium compared with lead. Several tests have been carried out, therefore, on the creep-resistance of aluminium of sheathing quality and, in particular, tests on tubing under internal pressure have been conducted. Such tests also give a sensitive indication of quality of tubing from the point of view of freedom from any special weaknesses, etc. Certain quality tests are laid down in B.S. 1471 (the standard specification for aluminium tubes mentioned above), including visual examination, tensile tests and a flattening test. From our experience of lead sheaths, we regard such tests as inadequate and have preferred to carry out fairly comprehensive pressure and related creep tests, as well as using standardised bursting tests for routine examination.

The difference in behaviour of lead and aluminium tube at ordinary temperatures is that lead tube will commence to creep (distend diametrally) slowly under pressures much smaller than those required to burst it rapidly, whilst aluminium tube will not. The thicknesses required to make lead tubing, of the quality used for gas pressure cable sheath, to withstand alone the internal pressure of 200 lb./sq.in. would be entirely uneconomical apart from the weight factor, etc., so steel or copper tape reinforcement around the sheath, to take up both the hoop and longitudinal tensions, must be used. Thicknesses of the same order as used for lead sheath and without reinforcement can be used for aluminium.

The hoop stress in a tube under internal pressure is given, if it be sufficiently thin-walled, by the formula,

$$f = Pd/2b$$

where P = internal pressure
d = (inside) diameter
b = wall thickness.

For thicker walled tubing, this tension is given (at the inner surface, where it is a maximum) by

$$f = \frac{P(D^2 + d^2)}{D^2 - d^2}$$

where D = outside diameter
d = inside diamter

providing the stresses are within the elastic limit. The difference between aluminium and lead can be summed up by stating that, whereas the latter will commence to expand for small values of f, aluminium will only commence to expand when a certain yield stress is reached. This corresponds to an internal pressure given by the formula :

$$P = \frac{(D^2 - d^2)}{2D^2} \quad Y$$

Fig. 11.—Failure at seam due to corrosion.

where Y = yield point (corresponding approximately to the proof stress) of the metal. Consider, for example, tubing of 2 in. diameter and 0·1 in. wall thickness. An internal pressure of 100 lb./sq.in. would produce a hoop stress of about 900 lb./sq.in. and at this value, lead of the quality used for pressure cable would burst in a day or two, whilst an alloy lead might last perhaps 2,000 hours or so. Aluminium of commercial purity (99·5%) would, if sound, last indefinitely at room (or cable operating) temperatures, and a pressure of about at least 600 lb./sq.in. would have to be reached before the tubing commenced to yield. The pressure would probably have to be increased considerably more for the tube to burst, the relation between tensile strength and bursting pressure being :

$$P = T \log_e \frac{D}{d}$$

where T = tensile strength

which works out for the above case, assuming a tensile strength of about 5 tons/sq.in., to about 1,000 lb./sq.in. pressure. A test favoured by the author on aluminium tubing for cable is based on the last two formulæ given above. A pressure corresponding to the first formula, using a predetermined value of the proof stress, is first applied to a suitable sample for 12 to 24 hours, and the pressure then raised in steps of about 50 lb./sq.in. until the bursting pressure is reached. This test is considered a more sensitive test for quality than a simple rapid-bursting test.

Table III shows some typical results of various rapid-bursting tests on aluminium tubing as used for sheathing, with the effects of small initial sinking for rounding-off and straightening, and of the final sinking clearly shown.

TABLE III.—BURSTING TESTS ON ALUMINIUM TUBE.

Size O.D. × Wall in.	Condition	Bursting Pressure lb./sq.in.	Hoop Stress lb./sq.in.	Mean Diametral Extension %
2·27×0·097	As extruded ..	950	10,000	10·0
2·19×0·101	Sunk 3·5% for straightening	1,100	11,000	3·6 (8·1% at point of burst)
1·92×0·105	Sunk 15% for final sheathing	1,450	12,500	0·5 (2·6% at point of burst)

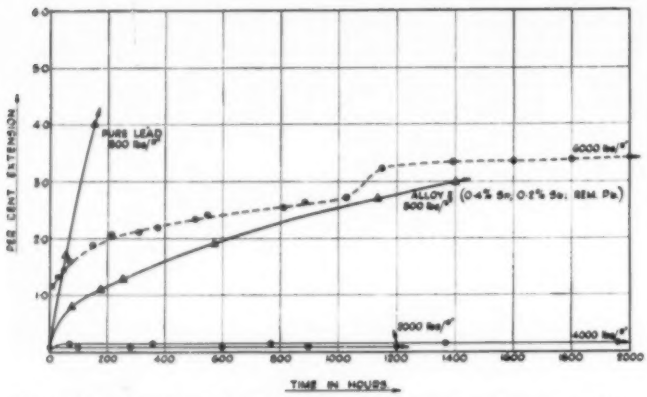


Fig. 12.—Constant load creep tests on aluminium strip of 99·7% purity at 70° C. compared with tests on lead strip at room temperature.

More sensitive tests for tube quality have been carried out by two long-time test procedures. It is normal in investigating lead or lead alloy sheathing for pressure cable to carry out long-time bursting tests, and the results often differ markedly from those of short-time tests. Extension results are often different, the type of fracture changes and defects show up more markedly. The application of a steady pressure to cause slow creep is all that is required for lead; for aluminium special procedures are necessary, and two which have been developed are as follows:

Pressure Increment Tests. These are carried out at a constant temperature of 70° C. The tube is subjected to a pressure of 250 lb./sq.in. for 1,000 hours, and the pressure then raised in steps of 50 lb./sq.in. after every 500 hours or so until yielding or creep begins, or failure takes place. A comparison of the pressure required with the initial pressure gives an idea of a sort of "factor of safety" involved in using the tube in practice as pressure cable sheathing. Another important feature of these tests is that weaknesses in the tube are shown up more markedly, *e.g.* any "seam" weakness.

Temperature Increment Tests. These are carried out at a constant pressure of 200 or 250 lb./sq.in. The tubing is subjected to a temperature of 100° C. for 1,000 hours and the increments of 25° C. for every 500 hours until failure occurs or yielding commences. This gives another sort of "factor of safety" measurement by comparing temperature of yield or failure with the maximum working temperature of about 70° C. in the sheath. It is also a sensitive test for quality.

Table IV shows some typical results of interest. In each case a good result is compared with one which showed some defectiveness at a seam.

A number of creep tests have been carried out on samples of strip taken from tube, the tests being conducted at 70° C. for determination of creep-resistance at this temperature. Fig. 12 shows some results in comparison with lead and Alloy E. The much higher stress in the aluminium will be noted. These samples are actually in the fully softened condition; the creep-resistance (at this temperature of test) is further increased when the metal has been cold-worked. There is often a marked difference in behaviour between materials from different sources. The behaviour of the sample at 6,000 lb./sq.in. stress would appear to be the result of the presence of large grains. Highly sensitive measurements of the creep of aluminium tube have also been carried out using resistance strain gauges fixed to the tube walls. These have shown that creep can occur at stresses well within the elastic range, but the results will not be detailed here. The creep which occurs is of the so-called "exhaustion" type, the rate of extension decreasing practically to zero after a time, but the effects obtained, although very small, were quite definite.

TABLE IV.—LONG-TIME TESTS ON ALUMINIUM TUBE

(*a*) PRESSURE INCREMENT TESTS (TEMP. = 70° C.)

Material and Dimensions	Pressure lb./sq.in.	Hoop Stress lb./sq.in.	Total Hours on Test	% Diametral Extension	Type of Failure
99·7% pure	250	2,960	1,120	0·3	
	300	3,557	2,050	0·3	
2·5 in. o.d.	350	4,150	2,600	0·3	Not failed
×	400	4,740	3,182	0·3	
0·1 in. wall	450	5,340	3,722	0·3	
	500	5,930	4,930	0·53	
	550	6,520	6,617	0·76	
	250	2,894	1,000	0·1	
99·7% pure	300	3,445	2,024	0·1	
	350	4,093	2,548	0·1	Failed in "seam line"
1·98 in. o.d.	400	4,620	4,334	0·1	with pin-hole perforation
×	450	5,200	5,456	0·40	
0·08 in. wall	500	5,780	6,811	0·5	

(*b*) TEMPERATURE INCREMENT TESTS (PRESSURE = 200 lb./sq.in.)

Materials and Dimensions	Temperature °C.	Total Hours on Test	% Diametral Extension	Type of Failure
99·7% pure	100	1,000	0·25	
2 in. o.d.	125	1,524	0·25	
×	150	2,000	0·25	
0·085 in. wall	175	2,182	0·25 (away from break)	Knife-edge burst
99·7% pure	100	1,000	0·15	
2 in. o.d. ×	125	1,500	0·15	
0·085 in. wall	150	1,600	0·83	Burst along "seams"

Corrosion of Aluminium

The problem of the corrosion resistance of aluminium cable sheathing in the ground is very much a problem of the protective value and life of the servings; it would be dangerous to rely upon the corrosion resistance of the metal *per se*, and foolish to assume that it compares really well with lead except under favourable conditions, such as, perhaps, in dry sandy soils or in neutral clays. It could be expected that aluminium might stand up better than lead in some cases, such as soils containing organic refuse, etc. in which lead is sometimes liable to severe attack, also in resisting bacterial attack, of which certain forms are reputed to be severe on lead (the sulphate reducing bacteria). On the other hand there is very little exact information to go on, and such information as exists is, on the whole, not very favourable as regards the resistance of aluminium itself to several soil environments.

In Table I were given some values of the electrode potential of aluminium compared with copper and lead. Note the high negative value of aluminium (some authorities it may be noted reverse the signs from those shown).

All metals will rapidly form a film of oxide on their surface, even in dry air, this film (unless tarnishing, etc. supervenes) being usually invisible. In the case of aluminium the film of alumina formed has particularly valuable properties ; it is coherent, non-porous and itself resistant to many types of chemical attack. There are several ways, both chemical and electrochemical (anodising) of increasing the thickness and protective value of this oxide film, but they will not be dealt with in detail here, there being little likelihood of their use for cable sheathing material.

Superpure aluminium has superior corrosion resistance to any other quality of aluminium or any of its alloys ; in fact it can be generally looked upon as a highly corrosion resistant material. The 99·5% pure metal has good resistance to atmospheric corrosion, and several of the alloys mentioned above are also reckoned as having fair corrosion resistance—most of them about the same order as the 99·5% pure metal.

The problems of corrosion in the soil offer particular difficulties not encountered in other environments. These arise from the complex nature of soils, their extreme variability in different localities, and even locally from point to point in a comparatively small area. Soils are not very easy to classify from the corrosion point of view ; some properties which are important in this connection are the fineness, uniformity, amount of moisture, acidity or alkalinity, degree of aeration, physical constitution such as whether clayey or sandy, presence of organic matter or any special chemicals peculiar to a given locality, and the electrical resistivity. Of importance also is the question of the presence or absence of stray currents.

Bimetallic contacts are avoided where there is any danger of corrosion. Copper and lead and other metals in contact with aluminium can lead to serious local accelerated attack on the latter. Other types of electrochemical action can also occur. Thus they can occur between two parts of the same piece of metal, either because one is of slightly different potential from the other, or because they are in somewhat different environments. In soil, this latter type of action would seem to be particularly liable to occur and if undesirable compounds are present their effect can be enhanced by variation in concentration (by the setting up of " concentration cells ") along, for example, a pipeline. Differences in degree of aeration of the soil at different points can also cause similar effects. On the other hand, the chemical activity of the soil itself is of great importance ; in the case of aluminium the concentration of chlorides or alkalies present is of particular concern. The danger from alkalies is due to the fact that they have a solvent action on the protective film of oxide ; thus, aluminium is very rapidly attacked in lime. When electrochemical action is concerned, the electrical resistivity of the soil is of importance because of the current flow concerned ; it is also of importance in connection with possible stray currents which may be present, and which can set up electrolytic action. The question of cathodic protection in general is worthy of some attention. Under suitable conditions many metals can be protected from corrosion by making them sufficiently cathodic, *i.e.* given such a polarity that any electric current flows into them from the environment concerned (positive ions discharge on to them). This can be accomplished by suitable electrical connections or by means of protective anodes. Magnesium " sacrificial " electrodes will protect steel pipelines in the soil in a similar way. Zinc and magnesium can exert similarly protective actions on aluminium, but there are possible complications. As with lead, but to a lesser degree, there is a danger of " cathodic attack " which limits the applicability of this type of protection.

The United States National Bureau of Standards has, for several years, conducted extensive soil corrosion tests on various metals, chiefly copper and copper alloys and steel, also a few tests on 99·25% purity commercial aluminium, an alloy containing 1·12% manganese and Duralumin of composition 4·1% copper, 0·62% manganese, 0·52% magnesium and 0·23% silicon. The samples consisted of strips 0·062 in. thick and the attack after 10 years in 5 different soils was studied. Details of actual weight loss (in oz./sq.ft.) are given in Table V.

TABLE V.—U.S. SOIL CORROSION TESTS
(Loss in oz./sq.ft.)

Material	Soil				
	Sandy Loam	Muck	Clay	Total Marsh	Alkaline Soil
Aluminium	0·086	D	0·35	0·18	0·49
Al Mn alloy	0·38	0·97	0·2	0·22	0·33
Dural	D	D	1·39	0·15	0·56
Copper	0·15	1·2	0·44	—	0·15
Lead (refined)	0·10	2·8	0·68	0·62	0·20

D—destroyed.

The attack can, in most cases, be characterised as fairly severe and the need for protection is clearly shown. On the other hand, some of the figures compare favourably with copper and lead attack. The aluminium, however, appeared to be much more liable to attack by pitting.

Other information would appear to indicate that attack on aluminium of commercial purity at least would appear to be comparatively mild in well-drained soils, and in most conditions it is no worse than or even better than steel. Generalisations of any kind, however, are dangerous at the present state of knowledge.

Various tests are under way in the Research Dept. of British Insulated Callenders Cables, Ltd., and in other interested research laboratories, but results cannot yet be gauged. Some reults of interest were obtained from a series of specimens buried at a Thames riverside site at Barking. These are of particular interest in including three grades of aluminium, superpure, 99·5% pure and 99·0% pure as well as various alloys. Table VI summarises the results on the aluminium samples.

There are very considerable variations for the different specimens (4 × 1 × 0·036 in. taken from rolled sheet), but the longer time results show the superpure metal in a definitely favourable light, whilst the 99·5% pure material is considerably better than the 99.0% purity. The soil concerned is made-up ground containing much cinder, etc., but gave a practically neutral test for acidity, etc.

One general point concerning aluminium corrosion is worth making here. Many tests by various authorities have given some indication that the rate of attack on aluminium by various corrosive substances falls off with time (according to an exponential law) until finally it almost ceases).[7] There is another important factor, however, arising from the fact that two different types of corrosion may be concerned ; general corrosion, *i.e.* a more or less uniform attack on the whole surface of the metal, and localised corrosion, *i.e.* pitting. The indica-

7 F. A. Champion, " Quantative Study of the Corrosion of Aluminium," *Transactions Faraday Society*, October 1945, **41**, p. 593.

TABLE VI.—CORROSION OF ROLLED STRIP SPECIMENS—BARKING SITE

(*a*) Super Purity Aluminium

Specimen	Burial Period: Days	% Loss of Weight	Average Number of Pits per sq. cm. of Surface	Maximum Depth of Pit: in.
A48	117	0·141	1·5	0·007
A10	117	0·88	3·3	0·017
A85	117	0·45	5·1	0·014
A53	529	0·505	4·3	0·024
A19	529	0·195	2·2	0·020
A18	529	0·25	2·6	0·014
A70	1,181	1·87	2·3	Penetration in 2 places
A31	1,181	0·974	2·6	Penetration in 2 places
A67	1,181	0·912	1·36	0·026
A40	1,181	0·787	1·4	0·028
A117	1,181	1·262	1·8	0·028

(*b*) 99·5% Purity Aluminium

Specimen	Burial Period: Days	% Loss of Weight	Average Number of Pits per sq. cm. of Surface	Maximum Depth of Pit: in.
B80	117	0·224	6·9	0·017
B118	117	0·086	1·8	0·005
B36	117	0·713	9·1	0·009
B62	529	0·716	1·0	0·017
B111	529	0·57	2·4	0·014
B25	1,181	1·74	2·9	Penetration in 5 places
B102	1,181	1·395	3·6	Penetration in 5 places
B10	1,181	1·263	4·5	Penetration in 2 places
B50	1,181	0·991	1·21	Penetration in 2 places
B88	1,181	0·435	2·0	Penetration in 1 place
B21	1,181	0·792	1·6	Penetration in 2 places

(*c*) 99·0% Pure Aluminium

Specimen	Burial Period: Days	% Loss of Weight	Average Number of Pits per sq. cm. of Surface	Maximum Depth of Pit: in.
C4	117	0·162	1·4	0·028
C48	117	0·191	3·4	0·024
C86	117	0·723	2·7	0·020
C97	529	1·825	3·5	0·028
C57	529	2·255	3·4	0·022
C16	529	1·012	1·8	0·017
C37	1,181	1·648	2·9	Penetration in 4 places
C78	1,181	1·821	2·6	Penetration in 1 place
C11	1,181	3·31	2·9	Penetration in 8 places
C68	1,181	1·441	1·3	Penetration in 5 places
C24	1,181	3·23	3·0	Penetration in 4 places

tions are that the latter type of action is particularly liable to occur with aluminium in soils, and can lead to much more rapid perforation than may be expected from studies in other corrosive media. Table VI shows that considerable pitting occurs even with the superpure aluminium, and it can be said, in fact, that it is chiefly against this type of action that aluminium cable sheath in the ground must be protected.

In the corrosion site referred to, unprotected tube failed, by the formation of several pits, in something less than a year. Other aluminium tubes wrapped in inhibitor impregnated tapes were still sound after two years; this leads to the question of the protection of aluminium sheathing with particular regard to the possible use of inhibitors.

Protection of Aluminium

As regards cable sheath, the main protection will be that offered by the serving. It is not proposed here to detail possible servings or to attempt any estimate of their efficacy. Bitumen has a powerfully protective action, both as a moisture excluder and from the fact that even if moisture percolates through, there is some tendency to hold back dissolved salts, etc., and the moisture which reaches the metal is, therefore, less corrosive in action.

There are several paints which are used for the protection of aluminium. Many contain zinc chromate or other chromates, more particularly for primers, afterwards being covered with a good gloss moisture-excluding finish. Of interest and possible use are the "self-etching" priming paints. These contain zinc chromate in a suitable vehicle, together with a substance such as phosphoric acid, which has an etching action on the aluminium surface to obtain maximum adhesion of the paint coating.

There is a considerable body of substances which can exert an inhibitory action on the corrosion of many metals. These include zinc chromate, sodium nitrite, sodium silicate, sodium benzoate and several other substances. Zinc chromate and certain other chromates are particularly useful for aluminium. They act essentially by maintaining the oxide film on the metal. Any water getting through to the metal dissolves some of the inhibitor compound, and this oxidises the aluminium, thus maintaining the protective alumina film. It will be noted that the inhibitor acts by solution and there are several qualities which have different solubilities. The more soluble ones are the more effective, but are liable to be leached out. Less soluble chromates (zinc tetroxychromate, barium chromate) are, therefore, sometimes used if there is likely to be a danger of leaching off.

A further point concerning drawn aluminium sheath is the possibility of stress-corrosion. This is an accelerated corrosion arising from the effects of internal stresses. Aluminium of the purity being used is not very susceptible to this effect, although some of its alloys are decidedly so. Certain alloy additions are also believed to decrease stress-corrosion. Common U.S. practice is to add 0·25% chromium to alloys liable to this trouble.

Another factor of importance in connection with aluminium corrosion is attack by cements, etc. Again there does not exist a great deal of authoritative evidence, and much is somewhat conflicting. Broadly speaking, however, attack is most severe for alkaline cements and those containing oxychlorides. Attack is also greatest where conditions are moist, when there is severe danger from many cements and plasters, so that deeply buried tubing is less likely to suffer than tubing near the surface. Some investigations of interest have been reported by Tronstad and Veimo.[8] They reported severe attack from strongly alkaline cements such as Portland cement, but less marked when the cement was aged and set. The much less alkaline gypsum showed much less attack, and the aluminium could easily be protected. Troubles due to differential expansion effects (the high coefficient of expansion of aluminium will be remembered) however, occurred.

Jointing of Aluminium Sheathing by Plumbing

For the plumbing of aluminium sheath, the first requirement is adequate tinning. After this has been done the usual plumbing alloys can be used with modifications in technique resulting from an increased tendency for "slipping," and the avoidance of contact with organic material such as tallow which blackens the aluminium.

Tinning of the aluminium offers no major difficulty, although considerably more difficult than lead or copper, etc. The chief requirement is to remove thoroughly the oxide surface film; ordinary fluxes (resin, killed spirits, etc.) will not do this. More active fluxes may be used—

8 Von. L. Tronstad and R. Veimo, *Aluminium*, December 1939, **21**, p. 839.

Fig. 13.—Section through plumb showing penetration due to corrosion.

such as a small percentage of hydrofluoric acid in petroleum jelly, or another suitable vehicle, or mixtures of nitric and phosphoric acids. Many of these, however, are not entirely attractive in practice, or leave undesirable residues. A method known as "reaction" soldering (or tinning) is worth mention. Some substances, such as stannous chloride, when heated in contact with aluminium react with it yielding, in this case, metallic tin which can be made to spread on to and wet the aluminium surface. These again, however, are not entirely attractive for aluminium sheath plumbing, because of fumes, technical difficulties and corrosive residues. A series of articles in *Light Metals* (January–April 1947) has given a good review of soldering practice for aluminium and alloys.

The method used in cable sheath practice is essentially that known as "friction soldering." The tinning is carried out by rubbing a stick of solder of suitable composition on the previously scratch-brushed aluminium surface. When a sufficient temperature is reached the solder tins the aluminium without the need for any flux. Further scratch-brushing of the tinned layer to ensure full action and proper wetting is also carried out, with further addition of tinning solder. A variety of tinning alloy compositions can be used. The majority are mixtures of tin and zinc, cadmium and zinc or tin, zinc and cadmium. Various (usually small) additions are often made of other elements such as copper, silver, aluminium and bismuth, and the mixtures sometimes contain lead. Tests have not so far shown any material advantages of these additions over the simpler compositions.

Both the tin-zinc and cadmium-zinc systems are eutectic-forming alloys, *i.e.* they form low melting-point mixtures as follows:

	melting point
Tin	232° C.
Zinc	419° C.
Eutectic: 90·5% tin, 9·5% zinc	197° C.
Cadmium	320° C.
Eutectic: 82·3% cadmium, 17·7% zinc	270° C.
Cadmium and Tin also form a eutectic of composition: 67·9% tin, 31·1% cadmium	177° C.

The main requirements of the tinning solder stick are: sufficient hardness to displace the alumina, good wetting power on the aluminium, and sufficiently low liquidus temperature to prevent burning of the cable tapes or papers. For example, good tinning properties and good strength can be obtained by the use of compositions in the whole range of tin/zinc mixtures from 90% tin down to 30% tin (or even lower). The corresponding liquidus temperature ranges from 200° C. for the 90% tin alloy up to 350° C. for the 30% tin alloy. At the latter temperatures, however, the heat required for tinning causes scorching of the cable core, and it would seem, therefore, that this fixes the upper limit of solder melting temperature allowable. Actually a temperature lower than 300° C. is desirable, as in the sheathing process.

A final important point concerning plumbed joints on aluminium is in connection with corrosion. Soft soldered or plumbed joints on aluminium can rapidly lose strength in moist or corrosive conditions. The effect is due to the electrochemical action set up between the solder and the aluminium. This can be demonstrated and studied by immersion of plumbs in brine. There is much attack on the aluminium adjacent to the plumb with quantities of flocculent aluminium hydroxide formed. Fig. 13 shows how the corrosion penetrates into the plumb and destroys the adhesion to the metal. The "joint" concerned has been tinned as described above and then plumbed with wiping solder. Plumbed joints on aluminium must, therefore, be carefully protected.

Conclusions

It is hoped that the above account has given a clear picture of the chief technical problems involved in the application of aluminium as a cable sheathing material and of the means taken to overcome them. The application is a comparatively simple one as compared with the complicated highly stressed structures to which aluminium alloys are so largely applied to-day, but it has involved a comprehensive study of the properties of the material and the methods of using it. The manifest advantages of lead as a cable sheathing material are such that very careful thought has to be given to any question of replacement, and it is probably true to say that there is no question at present of any wholesale replacement. However, where the mechanical property advantages, high endurance limit and greater creep resistance are of value, there is a particularly strong case for the use of aluminium, apart from economic factors. As regards availability, neither lead nor aluminium are at time of writing, in particularly free supply; as to the future, it is

of course impossible to foretell with any accuracy what the position is likely to be. One can however, foresee at least a long-term possibility of gradual replacement of lead by aluminium for the sheathing of several types of cable.

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Substitute Metals and Scrap Recovery

Institute of Metals Discussion

Arising from a suggestion put forward by Professor Murphy in his Presidential Address, the Institute of Metals last month held a General Discussion on Metal Economics. A brief account of the second session, dealing with scrap reclamation, secondary metals and substitute metals is presented here.

A GENERAL Discussion on Metal Economics, organised by the Institute of Metals, was held last month at the Park Lane Hotel, London. The papers presented at the morning session dealt with primary resources of ferrous and non-ferrous metals; in this account those presented at the afternoon session, dealing with scrap reclamation, secondary metals and substitute metals, are digested along with the ensuing discussion. The papers concerned, in order of presentation were :—

The Scope for Conservation of Metals (Ferrous and Non-Ferrous). By C. A. Bristow, A. J. Sidery, and H. Sutton (Ministry of Supply).

Economy by Standardisation of Alloys and of the Method of Reclamation of Scrap Metals. By C. Dinsdale (British Railways).

The Influence of Specifications on Productivity and the Economic Utilisation of Ferrous and Non-Ferrous Metals. By F. Hudson (The Mond Nickel Co., Ltd.).

Secondary Heavy Metals. By E. H. Jones (Capper, Pass & Son, Ltd.).

Secondary Aluminium and Magnesium. By Col. W. C. Devereux, C.B.E. (Alumin, Ltd.).

The Scope of the Conservation of Metals

In presenting this paper, MR. A. J. SIDERY referred to the problems arising from the growing world population, which was expected to increase by 50% by the end of the century, to something near to 3,000 millions. The doubling of the population in the last four generations had been accompanied by an almost fantastic series of inventions, the consequence of which had been that the drain on the earth's resources had increased on a geometric scale related to greater numbers demanding a greater variety of products from an infinitely more complex industrial system—a demand which was still increasing.

The General Situation.—Education brought with it an ever-increasing demand for higher living standards, and Edward Sampson, referring to the consumption of pig-iron per person in U.S.A. (790 lb. against 47 lb. for the rest of the world in 1945) warned against envisaging supplies for the whole world even remotely approaching those of the highly industrialised countries of to-day.

On the whole, mineral resources were wasting irreplaceable assets, and those connected in any way with metals had, therefore, a duty to see that metals were won, handled, used and re-used with due regard to the fact that the future peace, well-being and comfort of the peoples of the world is directly dependent upon the efficient use and conservation of our metals.

The mining and extraction of metals involved important considerations connected with mechanical equipment for mining, handling, transportation to concentration and reduction plants, the plants themselves, power supply, etc., and it should be remembered that increasing demands would lead to increasing exploiting of leaner and less favourably situated deposits.

Economical Use of Metals.—Metal economy could usefully begin at the design stage and co-operation between designer, production engineer, materials expert, and the producer of the semi-finished form could be very beneficial. Points to be watched included the use of materials difficult to obtain when easily obtained materials would be quite satisfactory; the use of material in excess of requirements; the waste involved in the production method employed; and the possibility of improved mechanical properties or protection against corrosion allowing of an overall saving.

Ferrous Materials.—On the ferrous side, the shortage of alloying additions emphasised the use of low alloy steels wherever possible. The change might involve redesign and extensive testing for many applications but the effort should be made. One of the important alloy additions was tungsten, and low-tungsten high-speed steels, or cutting materials free from tungsten, would greatly relieve the supply position. In connection with stainless steels, recent important developments would contribute greatly to economy in the use of niobium, except in cases where welding or exposure to high temperature, or both, were involved. The use of ferritic materials for gas turbine discs, a development made possible by engineering design, had achieved substantial economies in alloying elements, but for special applications strong claims for the elements used in heat-resisting materials would undoubtedly call for renunciation in other fields.

Non-Ferrous Materials.—Of the metals other than iron, copper, zinc, aluminium and lead were produced in greatest quantity but, with the possible exception of aluminium, demand was in excess of supply. The saving of other materials by the use of aluminium had already begun and a wide range of uses would go ahead as supplies allowed. Aluminium had already been used for conductors and if it could replace copper alloys in steam condensers a great saving of copper could be achieved. Other possible savings could be effected by the use of aluminium for cable sheathing, stronger lead alloys for battery plates, and reinforced plastics for bearings and gears.

Scrap Segregation and Recovery.—It was essential to

increase efficiency in the use of scrap and used material for, as Miller pointed out, unless an expanded production of low grade alloys from scrap could be achieved, it would be necessary to consider the adoption of processes for the treatment of scrap to recover in a high state of purity the constituent metals. There was scope for effective scrap segregation to save the necessity for identification.

Corrosion.—An aspect which had to be considered in discussing metal economies was the question of corrosion and the cost of combating corrosion. In many cases, the engineer tended to use excessive thickness to minimise the danger of a corrosion failure. Great economies had been achieved in particular fields by the development and use of corrosion resistant materials and of improved methods of protection.

The Forward View.—In looking to the future, Mr. Sidery said that for few of the industrial metals was there encouragement to hope for greatly or rapidly increased rates of world production. If only ductile silicon or silicon alloys could be developed, they might do much to relieve present and prospective demands for industrial metals and alloys. As it was, aluminium, magnesium and titanium claimed special attention because of their availability and scope for rendering useful service to man in future years.

Economy by Standardisation of Alloys and of the Method of Reclamation of Scrap Metals

In introducing the subject, MR. C. DINSDALE pointed out that there were many reasons why all Regions of British Railway should use the same metal for the same job instead of the variety which had existed previously. This was especially true of non-ferrous metals of which 20,000–30,000 tons were used each year for rolling stock alone, besides the amounts used in civil and electrical engineering projects.

After 1921, when the four main groups were formed from 123 separate companies, each group set about the task of standardising materials, but no country-wide standardisation took place. During the war years the need for economy in the use of tin reduced the number of tin-bronzes in use, and was responsible for the use of thinner white metal bearings or lower tin content bearing metals.

Non-Ferrous Metals and Alloys.—In 1948, a committee was set up by the Railway Executive to report (i) what non-ferrous metals were in use for rolling stock; (ii) what reclamation of non-ferrous scrap was being carried out; and (iii) to recommend the alloys and practices which should be used in future. The committee's main findings were:—

(*a*) *Cast Bronzes and Brasses.*—The Railway Executive's 17 "brass" foundries between them were casting each year 11,000 tons of 37 different copper-base alloys, whilst a further alloy was used for purchased bearing shells. Five standard alloys (a phosphor bronze, a leaded bronze, a leaded gun-metal, a yellow brass and a brazing metal) were recommended and introduced for castings for rolling stock and machinery. Standardisation of use was also recommended and introduced. It was difficult to assess the savings effected, but metal melting and scrap segregation costs should be reduced and a potential saving of 175 tons of tin and 100 tons of lead against increased zinc consumption was estimated.

(*b*) *Whitemetals.*—The Railway Executive owned some 6–7,000 tons of whitemetal and in 1948, 18 alloys with 13 different compositions were in use. Large variations in lining practice existed, for which no obvious reasons—except established practice—could be found. As a first step towards standardisation, the number of compositions was reduced to four—a high-tin lead-free white metal; a high-tin low-lead white metal; a lead-tin base white metal; and a lead-base white metal. Standardisation of purpose for each grade had not been worked out but extensive trials with lower tin content materials were being carried out.

(*c*) *Packing Metals.*—Although much cast iron and non-metallic material was used for packing, seven non-ferrous alloys were in use. These had been reduced to three—antimonial lead, copper lead, and leaded-bronze.

(*d*) *Wrought Metals.*—There was already substantial agreement in this field, due no doubt to the existing British Standards.

(*e*) *Solder and Brazing Metals.*—As British Standards existed for the various grades of soft and silver solders and brazing metals it was not found necessary to issue Railway Executive specifications.

(*f*) *Virgin Metals Purchased in Ingot Form.*—In 1948, it was the practice to purchase well-known brands from reputable makers who knew what the railways wanted. In order to standardise purchasing and stock-keeping procedures, it was found desirable to issue all-Region specifications.

(*g*) *Light Alloys.*—These were little used on rolling stock at present; when required they would be ordered to British Standards.

Reclamation and Renovation of Non-Ferrous Scrap.—British Railways differed from most engineering concerns in that its metals were in constant circulation throughout its own system, returning periodically to the workshops for re-use or scrapping. The L.M.S.R. had already developed scrap reclamation to a high degree, over 1,500 tons each of renovated white metal and brass and bronze ingots being produced each year. As different terms were in use in each Region for what appeared to be the same type of scrap, standard scrap nomenclature was introduced and a schedule listing where each type arose was prepared. Of the 27,000 tons of non-ferrous scrap produced annually in B.R. workshops, some 12,000 tons were sold and the rest used again, segregation in the stores simplifying the reclamation work.

Iron and Steel.—A Policy Committee was formed to recommend specifications for steels for rolling stock, etc., but, as most of the steels used previously were in accordance with British Standards, the resulting standardisation was not so spectacular as in the case of some non-ferrous metals. Most grey cast iron mixtures already included a high percentage of returned scrap (sometimes up to 95%). Further economies were not expected to be great.

The Influence of Specifications on Productivity and the Economic Utilisation of Ferrous and Non-Ferrous Metals

MR. F. HUDSON, in introducing the paper, said that the most that could be expected in the time available was to effect an approach by indicating one or two factors common to the subject as a whole.

Before maximum productivity could be obtained, in conjunction with the efficient and economic utilisation of ferrous and non-ferrous metals, consideration should

be given to the greater use of simplification, standardisation and specialisation methods, so that manufacturing operations could be properly planned. Simplification and standardisation, in particular, must go hand in hand, as too many standards might be just as bad as none at all. An endeavour should be made to plan production so that the minimum number of standard metals and alloys was required.

Multiplicity of Alloys.—As an example of the multiplicity of alloys available, Mr. Hudson quoted British Standard Schedule 1400 : 1948—Copper Alloy Ingots and Castings—listing 23 alloys, when the bulk of industrial requirements could be met by 10, grouped in seven main types. Agreement regarding tolerances on certain elements, normally considered as impurities, would reduce the number of alloys required still further. Such simplification would assist both productivity and subsequent scrap reclamation. It was interesting to note that the full use of simplification methods had led to a reduction in the number of alloys used in America. The introduction of B.S.1490 : 1949, covering aluminium and aluminium-alloy ingots and castings for general engineering purposes and limiting the number of alloys to 20 was a step in the right direction. Manufacturers should take every opportunity of educating users to appreciate that the use of a limited number of standard alloys and the ordering of components of the same design in sufficient quantity were vital factors in improving productivity.

Improvement in Casting Quality.—The next most important factors were design and quality control. Accurate correlation between test-bar results and mechanical properties obtained from the casting, together with control and uniformity of quality would enable many castings to be redesigned with a resultant saving of metal, due to the lower factors of safety necessary. The production of sound reliable castings called for a greater measure of co-operation between designer and founder than was usual. Furthermore, the use of high strength alloys would enable still greater savings to be effected.

In order to attain the greater uniformity and soundness of castings a number of factors merited careful consideration. These included (i) more general use of degassing methods in conjunction with the development of rapid control tests to assess melt quality ; (ii) more effective control of pouring temperatures ; (iii) more effective control of the properties of moulding and core sands ; (iv) improvements in running and feeding methods ; and (v) the adoption of a standard inspection procedure based on the assessment of actual casting quality, as distinct from the use of separately or integrally cast test-bars.

Secondary Heavy Metals

In this paper, MR. E. H. JONES dealt with the recovery in usable form of copper, zinc, lead, tin and antimony from sources other than their ores. From a study of the available statistics a table was drawn up giving the proportions of the total production used as (*a*) element ; (*b*) alloys ; (*c*) coatings ; and (*d*) salts, together with the fractions of each category recovered and, alternatively, those permanently dispersed to such a degree that recovery was economically impossible.

Reason for Losses.—Drawing attention to certain of the figures, Mr. Jones pointed out that the loss of 50% of the tin used in solders was due to the small amounts used and their wide dispersion. In the same way, the use of brass for small articles such as screws, fittings, etc., tended to lower the fraction of alloys recoverable. Quite considerable proportions of certain metals were used as salts and were almost wholly lost. In that connection it was interesting to note that a process for covering wood and steel with a coating as cheap and durable as paints containing lead and zinc would save from complete loss more of those metals than the most intensive efforts to increase recovery from scrap. Substitution had already begun, e.g., tin oxide had been replaced as putty powder by calcium carborate, and as an enamel opacifier by antimony oxide, which in turn faced competition from titanium oxide. The latter was also substituted for lithopone, which could in turn replace lead pigments in some applications.

Coatings.—In the case of alloys, the extent of secondary recovery depended on the size of the article, since that determined the difficulty of collection after use. With coatings, on the other hand, the general use of steel as a backing enable magnets to be used for collecting and the proportion recovered was decided by other factors.

As there was no method for removing small amounts of tin from steel it had to be stripped from the plate before remelting. The removal was effected by solution in caustic soda but the extent to which the detinning process was operated depended on a number of economic factors, including the price of tin, the coating thickness, etc. The value of the zinc on galvanised articles did not make its recovery worthwhile, and in any case it did not interfere with steel making.

Metals and Alloys.—The proportion ultimately recovered of the metal used as an element, or as an alloy of which it is the major constituent, depended mainly on the size of the article manufactured, small articles being dispersed. The effect of the price of the metal was most important. A price controlled artificially low and a consumption controlled by rationing must, in secondaries, produce a free market at higher prices, even if that were disguised by barter operations. If that did not happen, less metal would be recovered from dispersed sources than if the price were economically equitable.

Scrap Quality.—The collected scrap could be divided into two main categories : clean pieces that could be remelted and, after adjustment of composition, cast into ingots for return to the fabricator ; and material which had become attached to other metals or inorganic matter so firmly that physical separation was difficult or impossible. The latter were smelted and during the operation some of the metal might be lost. Smelting removed non-metallics, aluminium, magnesium, and some zinc in the slag, and volatilised zinc and cadmium which were caught as an impure fume. The metallic product would normally be an impure mixture and, if that could be refined and adjusted to a marketable alloy, the loss and work would naturally be less than if the elements had to be produced to ensure sale. The alloy must normally meet some specification or other, and for the maximum scrap recovery, that specification should be realistic and should not have unreasonably low figures for impurities.

Smelting Flexibility.—The introduction of new alloys containing elements not previously used in the same range could increase the problems of the secondary smelter considerably. Examples of such materials included tellurium in lead, arsenic and silver in solder, etc. The effect of relative prices, not only of metals but of fuel,

power, labour, etc., on the adjustment of the smelter's flowsheet was considerable—thus when the price of zinc was low, the lead smelter would use it to remove impurities and finally lose it in the slag. The optimum economic metal content of discarded residues, whether the slag of copper, tin and lead smelting, or the retort residue in the case of zinc, was varying equilibrium between value of recovery and the cost of work done, and was the subject of constant calculation. Truly had it been said that a smelter should never throw away anything, since the concentrations in nature were being steadily exhausted and the relative value of the metal increasing. Dumps of slag and residues then became valuable reserves.

Secondary Aluminium and Magnesium

In his outline of United Kingdom secondary light alloy recovery, Col. W. C. Devereux pointed out that its establishment as an integrated and scientifically controlled process had lagged behind that in Germany and the U.S.A. By a vigilant policy of laboratory control of quality, the smelters set about overcoming the prejudices against their products, and by 1939 it was generally accepted that secondary alloys were metallurgically equivalent to those made from primary material. The advent of war brought about a complete change in the status of the industry and since the war the use of secondary aluminium had continued to increase until a yearly rate of some 100,000 tons had been achieved for the first half of 1951. In the case of magnesium also, progress had been made, and it was estimated that between a quarter and a third of the present annual consumption of 5,500 tons was met by recovery from scrap.

Sorting.—Hand sorting of large scrap was still done mainly by experienced but not technically trained workers, with the support of a few simple tests. It was possible that instruments measuring electrical properties would be developed to assist rapid sorting, but one firm had effected a striking improvement by putting a skilled chemist on the job to guide and support the sorters with various tests and better general technical knowledge. Large scale sorting of small pieces was only economical when mechanised, and was so far limited to the magnetic separation of ferrous metals. Large scale "sink or float" experiments were technically successful but the market situation did not permit exploitation of the process. For composite structures with other metals separation was often effected by liquation.

Melting and Metallurgical Treatment.—A division of opinion existed on the relative merits and limitations of the rotary and reverberatory furnaces. The Americans with their larger outputs favoured the latter, but the short melting cycle and great flexibility had firmly established the rotary furnace in Europe. A recent development was the use of the low-frequency induction furnace.

Refining of aluminium and magnesium was confined to the elimination of inclusions and gases as all the metallic material could be incorporated into useful alloys. The treatment consisted essentially of melting under a flux the action of which was to lift the oxide from the liquid melt by surface tension and keep it enveloped in slag.

The only industrial refining operation in the more classic sense was the elimination of magnesium from aluminium alloys. During the war the economic barrier to further refining was removed and processes for the elimination of other elements were developed. The electrolytic three-layer process carried out on a technical scale in Germany aimed at producing pure aluminium, as did the catalytic distillation process, which was just coming out of the laboratory stage and used less power than the three layer process.

As a consequence of the high class analytical control necessary at all stages of scrap recovery, sorting, blending, furnace control, and release, the art of analysis, particularly of aluminium, had received valuable contributions from the work of the laboratories of the remelting industry.

The production of secondary magnesium alloys followed similar lines, with the well-known differences in fluxing and melting treatment. In the case of turnings and sawings, the economy of recovery was reduced by the precautions to be taken in storage and transport.

Scrap Arisings.—There were various forms in which scrap could arise, the first being process scrap at the fabricators, which was never handled by the secondary smelters. 'New scrap' arose at the second stage of manufacture, at the works of the users of semi-manufactures, and ranged from massive and fairly readily identifiable forms to swarf and turnings. Frequently the more solid types of 'new scrap' were returned direct to the fabricator. The third form 'old scrap' comprised obsolete, damaged or worn out machinery, etc.

'New scrap' arisings were directly related to current consumption of aluminium, whilst 'old scrap' only returned after many years. Before the war, 70% of secondary metal in the U.S.A. derived from 'old scrap,' but since then, 'new scrap' had exceeded 'old scrap' by a considerable margin.

Supply and Demand.—In most industrial countries, the proportion of secondary metal, excluding process scrap, incorporated in the total aluminium consumption tended to be around 30%, but Kom calculated that there might come a time when, under stable conditions of aluminium consumption, 75% of the total demand could be supplied from secondary metal.

Overall U.K. production of secondary ingot had been in excess of consumption since 1940, but in the last year consumption had increased sharply and current stocks would be exhausted by the end of 1952. A similar position existed in the case of scrap arisings.

What made attempts at accurate forecasts very unreliable was the dynamic nature of such a young industry, particularly in regard to the constantly changing pattern of uses. For instance, before the war a very high proportion of aluminium went into moderate life-span machines, and it would be many years before such material returned as scrap. On the other hand, there had been a rapid increase in short life uses, such as packing; the difficulty there was that of collection.

Influence of Export.—A further factor influencing the secondary metal position was the high rate of export of manufactured goods, many of which used large quantities of aluminium. In that way important amounts of "potential" light-alloy scrap were sent abroad each year.

It appeared that a shortage of scrap was likely in the next few years unless drastic steps were taken to improve the efficiency of scrap collection and utilisation, a responsibility which concerned not only scrap merchants

and secondary smelters but the fabricating industry and all users of light metals.

Discussion

The discussion was opened by MR. G. L. BAILEY (Director of the British Non-Ferrous Metals Research Association) who said he would like to suggest that the question of substitute metals must be divided into two parts. As materials such as aluminium, magnesium and titanium became more available, the price factor and availability would cause people to use them in place of other metals and that should really be regarded as replacement rather than substitution. The real substitution problem was the short term replacement of one material by another in spite of the fact that it might be uneconomic in money or in manpower or in some other respect. Substitutions had to be made, if there were a necessity for economising in the use of a particular metal, either by non-metallic materials or by a very complicated system of ceasing to use metal *A* for a certain purpose, because that was not important, in order that it could be used in place of metal *B* for something which was important. It was all very complicated and tended to waste technical effort unless a permanent replacement resulted.

On the question of secondary metals and reclamation, Mr. Bailey said he was impressed by the efforts of the aluminium industry in that respect, and he would like to see the scale of operations of the secondary copper industry greatly increased. One aspect of reclamation that did not appear to have been touched on was the recovery from liquid residues, such as pickling and plating solutions. In particular, the drag-out loss in plating baths was of considerable importance, and much copper sulphate solution had found its way into the drains when it could have yielded both copper and sulphuric acid.

Mr. Hudson had linked specifications and productivity, and in discussing this point Mr. Bailey emphasised the necessity, when cutting down the number of specifications in use, for choosing the right alloys from the productivity point of view. He was rather surprised at British Railway's decision to omit 85 : 5 : 5 : 5 gunmetal from their selected alloys as he thought it would have done most of the things the 86 : 7 : 2 : 5 alloys did, with a considerable advantage in productivity as well as price.

In conclusion, Mr. Bailey stressed the importance of the most economic use of the metal available. The argument was often used in industry that certain things had been looked into before, and it was found they did not pay. With present metal prices, a good many of those things were worth looking into again.

Continuing the discussion, MR. D. A. OLIVER said that the morning session had shown that there was no need for panic so far as Mother Earth was concerned. On the other hand, metal shortages were not a figment of the imagination, and if appreciable economies were to be made over the national industrial field, a considerable amount of re-design, development and testing must be undertaken. As an example, Mr. Oliver quoted the U.S. television industry, which had its supplies of metal cut by one-third. By re-design, sets which weighed 28 lb. were reduced to 17½ lb. and, though they might be a little less efficient on power consumption, they were perfectly satisfactory sets.

Mr. Oliver then gave consumption of scrap figures for a number of metals taken over the country as a whole and comparing 1947 with the first half of 1951. In the case of copper, the figure for 1947 was 35%, and for 1951, 40%, showing that the price structure or the shortage structure had resulted in an uplift of a considerable amount. For lead the two figures were 43% and 49%, and for zinc, 30% and 36%. For steel the figures showed a drop from 53% to 51% due to the necessity to use more pig and less scrap. It seemed as if there was a move in the right direction for returning scrap direct to the makers, thus resulting in greater overall efficiency.

Reference was made by Bristow, Sidery and Sutton to the possibility of replacing copper bearing condenser tubes by aluminium ones. Whilst in America, the Productivity Team on Scarce Materials heard of a case in which aluminium tubes were actually in use, with satisfactory results to date.

Another factor which was helping in the economy drive, particularly in ferrous metals and highly complex alloys, was the use of the oxygen lance. By that means it was possible to get the carbon down to specification without losing large amounts of alloy.

DR. U. R. EVANS (Cambridge University) referred to the question of protection against corrosion, and pointed out that whilst in the case of a coating like zinc, which was anodic to the steel base, it might not be too far out to say that the life was proportional to the thickness, that was only true for uniform coatings. It was, therefore, dangerous to reduce the coating below that at which uniformity was possible. With nickel, which was cathodic to steel, the case was entirely different and a very small reduction in thickness could seriously impair the effectiveness of the protection, and Dr. Evans was worried at the possibility of our reputation for high quality in export goods being lost due to false economy in materials. There was little doubt that greater care in the choice and application of protective coatings, whether metallic or non-metallic, would contribute to metal conservation quite as much as the organisation of the return of the uncorroded residues to the metallurgical industry in the form of scrap.

In a written contribution read at the meeting, MR. H. J. MILLER (British Copper Refiners, Ltd.) dealt with some aspects of the supply and utilisation of copper and copper-base scrap materials. The main sources were 'new scrap,' 'old scrap,' and residues from the metallurgical industry, the last-named covering much smaller amounts than the other two.

Whilst over extended periods there might be a fairly constant flow of scrap, within short periods there might be enormous variations. Process scrap or 'new scrap' became available a few weeks or months after the manufacture of the strip, rod, sheet, etc. In conditions of expanding trade a temporary scrap shortage would arise, whilst in contracting trade it would lead to a glut. The amount of 'old scrap' from demolition or salvage operations was subject to an altogether different series of variations. After an average life of 25 years, some 65% of copper and copper alloy products might be expected to be recovered; thus the quantity of 'old scrap' coming forward bore a relationship to the metal put into service in the previous generation. The supplies of 'old scrap' were subject to a peculiar set of laws, and it was for those reasons that the metallurgical industries could not rely on stability except over long periods.

Fears had been expressed by primary-metal producers that scrap metal supplies could exert a predominating influence on their livelihood, especially under conditions of contracting trade. Eventually old copper scrap supplies could exceed the supplies of virgin copper and, although he could not visualise it happening for a long time, there was evidence of the validity of the contention in the experience with lead.

Under conditions of primary-metal shortage, many unnatural forms of incentive to employ scrap were experienced, and too much emphasis should not be placed on present conditions, and on some of the difficulties encountered.

For convenience, Mr. Miller regarded the copper industry as consisting of eight sections: (1) copper for electrical products; (2) other fabricated copper products; (3) brass strip, tubes, etc. (alpha brass); (4) brass rod and sections (alpha-beta brass); (5) brass castings; (6) gunmetal and bronze castings; (7) miscellaneous (including special alloys); (8) copper sulphate. These sections differed in their capacity for absorbing scrap, because of the fact that the inevitable impurities associated with scrap had different effects. On the average, the eight groups could absorb up to 40% of total scrap, so that the virgin requirement was 60%. Actually in pre-war years in Britain, the figures were probably nearer 30% scrap and 70% virgin metal. It was not reasonable to expect that the proportions of scrap could be increased to any considerable extent over present values. Indeed, if, as seemed inevitable, there were an extended demand for semi-fabricated materials to have more uniform and superior properties, then the amount of scrap used might have to be reduced.

The overall conclusion was that it would not always be possible to absorb all the arisings of 'new' and 'old' scrap directly, and the excess would, of necessity, have to be treated for recovery of the constituent metals. As that would be a more costly procedure, every effort should be made to ensure a greater direct use of scrap, an end which would be attained more easily if proper attention were paid to segregation of 'new' and classification of 'old scrap.'

The Production of Relief Designs on Aluminium Surfaces by Anodic Oxidation

By G. O. Taylor, M.S.E.(Mech.), A.I.Prod.E.

An account is given of a method of producing relief designs on aluminium which is based on the intensely hard anodic film produced by anodising in sulphuric acid under suitable conditions. The process is capable of a number of variations whereby an interesting range of decorative finishes is possible.

IN the decorative metalworking and fancy goods trades, aluminium and its alloys are being increasingly used where other metals were previously employed. Much of the impetus in this direction results from a greater appreciation of the anodising process with its wide possibilities for the production of decorative effects.

Although the potentialities of this process have been discussed from time to time, an aspect that seems to have received little attention is the possibility of producing relief designs on aluminium surfaces through the medium of the anodic film. In recent years many fine examples of dumb waiters, trays and similar articles with figured surfaces have appeared on the market and afford typical instances of applications where relief-designed surfaces can be used with advantage.

There are several methods by which relief designs can be produced by mechanical working of the metal surface. For example, small areas can be impressed with a design in a coining press; coils or sheets of metal can be passed between engraved rolls; or, as in the "Imprest" process, a sheet of soft aluminium with bright rolled surface is placed under a paper stencil and the two together are passed through heavy rolls. The compression "raises" the metal into the areas corresponding with gaps in the stencil to produce a design slightly in relief. Each of these methods has its specific use, but mechanical compression processes are expensive in initial tooling and require quantity production to be economical, and few manufacturers of decorative metal goods have the rolling equipment necessary for producing designs by these processes.

The Anodising Method

A simple method which requires no expensive equipment and is suitable for small and medium scale production, is based on the unique property of the metal for forming an intensely hard oxide film when anodised under suitable conditions in a sulphuric acid solution. With controlled conditions of (*a*) acid concentration, (*b*) electrolyte temperature, (*c*) applied voltage, and (*d*) duration of anodising, oxide films that are not only extremely hard, but of appreciable thickness can be formed. For pure aluminium, and the majority of its alloys available in rolled sheet form, suitable conditions obtain when the electrolyte contains 15% by volume of sulphuric acid and the operating temperature is maintained at 60–65° F. The voltage applied can vary from 10 to 15 and the duration of treatment from 30 to 45 minutes. In general, providing the metal surface is not "roughened," the longer the anodising period, (up to 45 minutes) and the higher the voltage, the thicker and harder will be the resulting oxide film. After suitable anodic treatment, the metal is well swilled, first in cold, then in hot water, to allow it to conserve heat to dry off without wiping.

When the surface is dry, the design required to stand in relief is applied, using oil-bound lithographic printing ink, cellulose or oil paint, varnish, or any other medium that will act as a temporary resist. For ease of

application and speed of operation, printing with lithographic ink, suitably thinned out and applied with a rubber squeegee through a silk-screen frame, is an ideal method which will be dealt with later in more detail.

The second stage in the process is the removal of the oxide film from those areas of the surface forming the background, i.e., not covered by the resist. This is carried out by immersing the metal in a hot 10% solution of acetic acid, or a hot 10% solution of chromic and phosphoric acids in equal parts by weight. The second solution is to be preferred, since it is without the pungent odour of the first. Immersion in either solution for a few minutes will remove the unprotected oxide film, to leave the areas covered with resist unaffected and standing in relief, as will be found by scraping the tip of the finger nail across the surfaces, when the "high" places will be felt to be bounded by distinct ridges.

To a degree dependent on the conditions under which the oxide film has been formed the exposed surface will still be comparatively smooth, since the solutions used to remove the film are without action on the metal itself. It is preferable that, before anodising, the aluminium should be polished or in the bright rolled condition, as this facilitates the next operation, which is mechanical polishing of the entire surface using a lightly greased mop. When this operation is carried out it will be found that the unprotected background will easily finish to a bright polish with only light pressure on the mop. The relief areas still covered with anodic film remain unaffected, due to the hard nature of the coating. The lithographic ink is automatically removed during this operation.

The metal of the background areas, being relatively soft, is to some extent removed in the polishing operation, the harder relief areas being left "proud" to a surprising degree. The final effect is of a prominent, silvery-white figuration, on a bright polished background, the design being integral with the surface and resistant to any normal wear and tear.

Variants of the Process

The process is capable of a number of variations. If, immediately after anodising, the metal is immersed in an aqueous dyestuff solution to colour the film before drying off and printing, the design ultimately appears in bright colour on the polished background. In a further variation, the metal, after printing and removal of the background, is not polished, but is re-anodised for a short time, say, ten minutes. The design then appears silver-white on a silver background, or, if the re-anodised metal is dyed to a pale shade, the design is in silver or deep colour on a tinted background. The versatility of the process is such that many pleasing and ingenious variations can be achieved.

As mentioned earlier, the silk-screen method of printing is an ideal and economical means of producing the designs for this process, the apparatus being simple both to make and operate. Basically, it consists of a sheet of fine meshed silk stretched taut in an adjustable wooden frame, which is hinged at one end to a base board, suitably marked to allow the sheets of metal to be registered accurately under the design that appears in stencil fashion on the silk.

The design to be reproduced is first cut on a special two-layer paper, which is laid on the taut silk and ironed with a hot flat-iron. This has the effect of melting the face of the paper carrying the cutout design so that the meshes in the silk are filled at those areas where the design has not been cut away. When the backing paper is stripped off, a perfect stencil appears in the silk itself. In this method of "stencil" making, the "joins" necessary to hold together normal stencils are absent.

In the printing operation, the sheet of anodised metal is registered on the baseboard and the screen is lowered so that the silk is in intimate contact with the metal surface. When a rubber squeegee is drawn down the screen, suitably thinned lithographic ink can penetrate the silk only where the meshes remain open to correspond with the required design.

Stencils for simple designs can be cut by hand but if very fine delineation or considerable detail is required, the screen is best produced by a photographic process. The design required is first made as a black and white drawing which is photographed to produce a negative.

The silk is coated with a light-sensitive bichromate-gelatine mixture in a dark room, and allowed to dry. When the emulsion has dried, the negative is placed on the silk and the whole is exposed to strong light, to produce a "print" in the silk. Where there are no lines on the negative the emulsion is rendered insoluble by the action of light, so that when the screen is ultimately washed in water, the areas corresponding with lines of the design are open, due to washing out of the emulsion still soluble.

Recent developments in the silk screen process have enabled production methods to be applied successfully to the printing of cylindrical and tapered surfaces, so that further possibilities arise in that relief designs can be produced not only on flat metal, but on aluminium articles having curved surfaces.

Packaging of Sheet and X-Ray Films

A FURTHER important step in the rationalisation of quantity packaging of sensitised photographic material will come into operation in the not too distant future. Sheet films and X-ray films will then have a basic minimum packing unit of 25 sheets.

At present sheet films are packed in units of 24, up to and including size 8 × 10 in. and 18 × 24 cm., and of 12 sheets for larger sizes. The new minimum unit will be 25 sheets for all sizes up to 20 × 24 in. (50 × 60 cm.) with the possibility of a 50-sheet unit for certain sizes in particular kinds. American and continental practice already favours a 25-sheet basic unit, with some variation for large sizes, while the 50- and 100-sheet units for popular sizes and kinds are finding increasing popularity in America.

The ever increasing importance of the export trade has, no doubt, influenced British Manufacturers of sensitised materials to adopt American and continental quantity packings, while an additional factor is that economies under the new scheme should, to a certain extent, help to offset the rising cost of packing materials.

With X-ray films the present practice is to pack 24- and 72-sheet units of folder-wrapped films in sizes up to and including 12 × 15 in. and 30 × 40 cm. and to provide 12-sheet units for larger sizes. In future all sizes will be packed in 25- and 75-sheet units. Envelope-packed X-ray films will, for the present, remain unchanged as a 12-sheet unit, but this in due course may be changed to a minimum 25-sheet unit.

New Plant for the Production of Heavy Steel Forgings

Developments at Hadfields Limited

The new heavy forging plant of Hadfields, Ltd., was opened on November 8th, 1951, by H.R.H. the Duke of Gloucester. A brief account is presented of the salient features of the plant, including reheating, forging, and heat treatment facilities.

TO improve their heavy special steel forging facilities, Hadfields Limited have recently erected and equipped a completely new forge unit with two air hydraulic forging presses of modern design, one of 2,700 tons and the other of 1,500 tons capacity, together with the necessary re-heating furnaces and heat treatment plant. The whole project has been co-ordinated by the Works Re-organisation Department of the Company and the aim throughout has been to instal a plant which can effectively and economically cope with present and anticipated requirements. It will be possible to deal with ingots up to 45 tons in weight and to produce forgings up to 40 in. diameter or up to 40 ft. long, whilst rings up to 12 ft. in diameter and sleeves up to 6 ft. diameter and 10 ft. long will also come within the capacity of the new plant.

The general layout and the choice and design of individual units have been determined with the object of effectively and economically dealing, in the correct production sequence, with both present and future requirements.

The Building

Located near to the steelmaking plant and conveniently placed in relation to the machine shops, the forging building covers an area of some 122,000 sq. ft. and consists of four bays. Of these, three—the forge bay, the furnace bay, and the heat treatment bay—have each a crane span of 80 ft. with a height of 52 ft. from floor level to crane rail level, and a total length of 386 ft. The stock bay is of the same length but has a crane span of 51 ft. 9 in. and a height of 39 ft. 6 in.

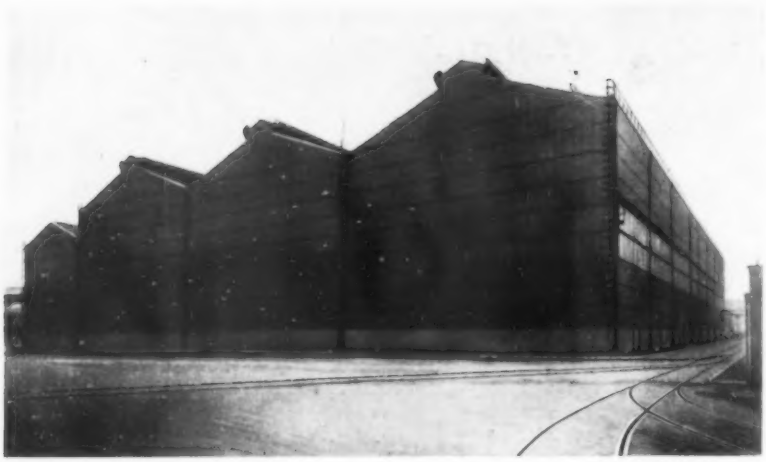
The foundation requirements for the new shop involved a large number of isolated foundation blocks and, in order to minimise timbering of individual excavations, the whole site was excavated to minus three feet, with a further increase to minus ten feet in the area occupied by the foundations for the furnaces and the presses.

Owing to the nature of the ground, as revealed by test borings, it was decided to drive in pre-cast concrete piles, 25–30 ft. long, for the majority of the columns, the remainder being formed of the usual rectangular concrete blocks. The furnace foundations were constructed of concrete suitably reinforced, and the press foundations, which were also of reinforced concrete, were taken down to a depth of some 40 ft. Two watertight cylindrical pits were required in the heat treatment bay to house two tanks to be used for quenching purposes, each 8 ft. diameter by 54 ft. deep, with their axes vertical and with the top edge of the tanks just below floor level. Each pit was formed of cast iron segment rings which were bolted together, caulked and pressure grouted.

General view of the forge bay.

After completion of the foundations the site was backfilled with furnace slag and a 6 in. concrete floor was cast in the stock, furnace and heat treatment bays. The floor in the forge bay consisted of 2 in./4 in. thick steel plates laid on sand. The excavation, piling, concreting and builders work was carried out by Sir Robert McAlpine & Sons (Midland) Ltd.

The forge building is of the usual steel framed mill construction fitted with continuous ridge ventilators. The building is completely closed in, being sheeted to within 7 ft. of ground level, with the exception of two runs of vertical glazing in the side sheeting of the heat treatment bay, which are included to give additional daylight in the shop. The walls are of brickwork 7 ft. high. The Consulting Engineers for the building were Messrs. Bylander & Waddell, London, and the 2,700 tons of steelwork used were supplied and erected by Messrs. Banister, Walton & Co., Ltd., in association with Cargo



General view of the forge building.

Fleet Iron Co., Ltd. The sheeting was fixed by Messrs. Carter-Horseley (Engineers) Ltd., and the glazing was provided by Messrs. Mellowes & Co., Ltd. A total of 45,000 superficial feet was involved in glazing whilst the approx. area covered by corrugated sheets was 194,300 sq. ft.

As was stated earlier, the building comprises four bays, each 386 ft. long. Three have a crane span of 80 ft. and a height to crane rail level of 52 ft., whilst the stock bay is 39 ft. 6 in. high with a crane span of 51 ft. 9 in. This small bay occupies a flank position and houses the hydraulic pump house and sub-station as well as providing space for stock. The next bay is the forge bay with its two hydraulic presses situated one at each end on the side nearer the stock bay. Along the other side of the bay are the fronts of the eleven reheating furnaces, the furnaces themselves being mainly in the furnace bay, back to back with the nine heat treatment furnaces. The latter furnaces face the heat treatment bay which also houses a number of oil and water quenching tanks and the pyrometer house. Adequate road and rail access has been provided and the broad gauge rail tracks, and transfer tracks permit of easy and rapid movement of forgings both ingoing and outgoing.

Forging Plant

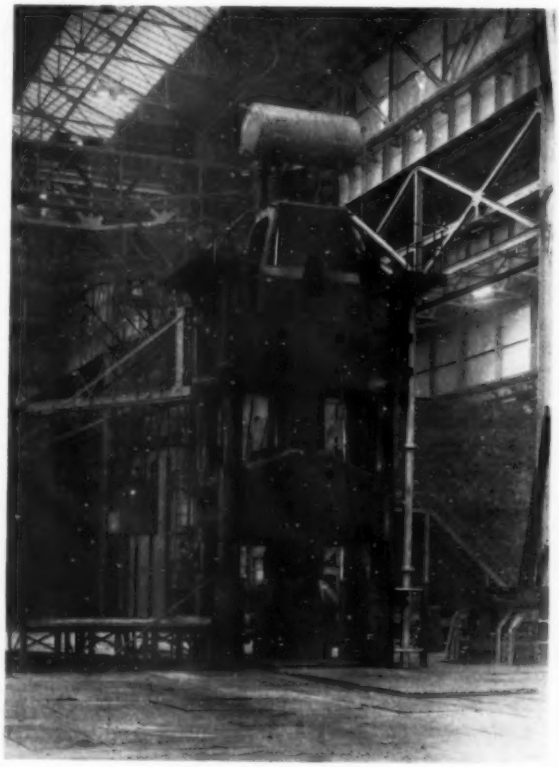
Two forging presses, one of 2,700 tons power and one of 1,500 tons power, operated by a common pressure water station, have been installed. The design and supply of this plant was entrusted to The Loewy Engineering Co., Ltd., and it was manufactured by F. B. Engineers, Ltd., Sheffield, and Light Machines, Ltd., Yeovil.

One of the main features of the press plant is its very high working speed and ease of operation over a wide range of forging work. To make this possible, and also to allow for the greatest flexibility, it was decided to instal an air hydraulic accumulator station in preference to a direct pump drive installation.

Trial runs so far made have shown that penetration speeds of 6 inches per second, or more, can be achieved on both presses at full power, whilst for planishing and finishing operations, well over 100 strokes per minute have been maintained. These high operational speeds are of particular importance in the case of forging highly alloyed steels, where the maximum amount of work must be accomplished per heating cycle.

The press plant has a number of interesting characteristics, some of which are referred to below.

The suspension of the top entablature on the presses is a special feature by which it is possible to dispense with nuts or collars on the main columns which are otherwise required on the underside of the top entablature. The design embodies a small crosshead which rests on the head of the columns. From this crosshead are suspended forged steel tie bolts which hold the entablature securely against the top column nuts. Both presses are provided with three point guiding of the moving crossheads to take up the effects of eccentric loading or other forces occurring during forging operations. The application of this type of guiding in a three cylinder press is novel and is achieved by having the centre cylinder rooted into the moving crosshead, the top end of the cylinder sliding in a sleeve fitted into the top entablature. The three cylinder design is used for the 2,700-ton press so that three pressure stages can be



1,500-ton forging press.

selected at will, to suit the resistance of the work at various stages of the forging operation. The smaller press has one cylinder.

Each press is provided with a moving table which is divided into three parts, a centre and two outer portions. The table sections can either be connected together as one table or the two outer tables can be operated independently by special double-acting hydraulic cylinders, a draw-bar being provided for coupling the tables to the hydraulic movement. This gives the fullest possible flexibility of operation when dealing with a wide variety of forging work. Further, each press has a multi-station ejector to facilitate handling during high speed piercing and die forging work. Hydraulic table locks are also provided for accurate centering of those tables during the carrying out of such work. The table and ejector controls are interlocked electrically so that movement of the ejector can only take place when the tables are in the ejecting position, and also so that the tables cannot be moved until the ejectors are in the retracted position.

The crossheads of the presses are narrow in order to allow for a close approach of the handling equipment to the anvils during working. Shock absorbers are installed to ensure smooth and shockless operation. Lubrication of all moving parts has been adequately provided for by means of mechanical lubricators and grouped nipple assemblies.

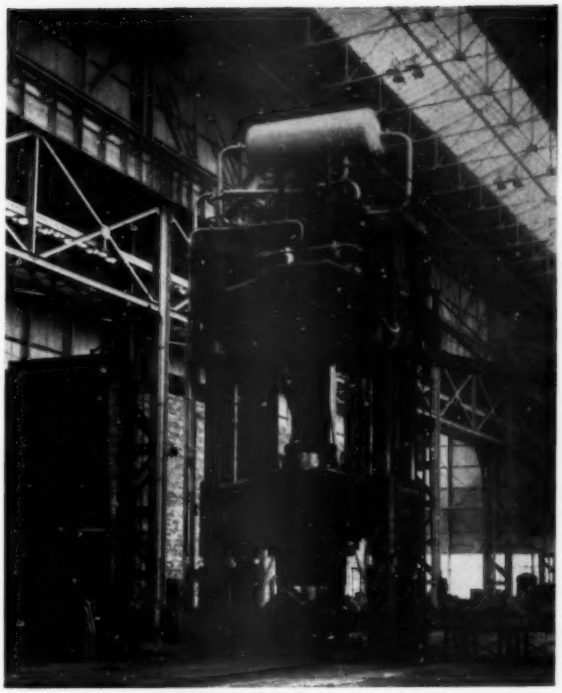
The main control valves for the presses are operated by Servo valves which give finger-light sensitive control, and enable a high working speed to be maintained without effort on the part of the operator. Low pressure water pre-filling devices are provided for the idle movements of the presses so that the high pressure is used only during the actual pressing strokes. This, combined with the three-stage design of the larger press, results in maximum economy.

The air hydraulic pressure water station consists of an accumulator with air and water bottles and five high pressure hydraulic pump units. This station is housed in a two storey brick building erected in the stock bay between the two presses. This building also houses an electrical sub-station for the supply of electricity to the pumps and the forge building. For reasons of space, the hydraulic pump units are mounted on separate floors, three being on the ground floor and two on the upper floor. The size of the accumulator ensures an adequate reserve of pressure water when both presses are working at high speed under full pressure. Four pumping units are normally in operation, the fifth unit acting as a standby, but the pipework and the controls are arranged in such a way that any of the pumping units may act as spare. The flow of water from the pumps to the accumulator and from the accumulator to the presses is automatically regulated in accordance with varying requirements.

Electrically controlled and hydraulically operated valves are provided which control the supply of the pumps through by-pass apparatus, and the whole system is designed to ensure maximum economy of working under all operating conditions. Adequate safety devices, both audible and visual are installed to ensure safe and foolproof working of the whole plant.

Cranes

The building is served by the following cranes, all operating on a 230 volt D.C. supply :—



2,700-ton forging press.

2—40-ton cranes with 10-ton auxiliary hoists in the heat treatment bay ; 1—10-ton crane in the furnace bay, which has been installed chiefly for maintenance purposes ; 1—40-ton crane with auxiliary hoist of 10 tons capacity in the stock bay for the handling of ingots. These four cranes have been supplied by The Butterley Co., Ltd., Derby.

In the forge bay three special forging cranes of Sir William Arrol manufacture have been provided, two being of 75 tons capacity with separate 20 tons auxiliary crabs, the remaining one of 40 tons capacity with a separate 10 tons crab. The driver's cab on all these cranes is at a height of approx. 12 feet from floor level, thus enabling the crane operator to have a full view and close control of the forging movements under the respective presses.

Removal of ingots from the furnaces is carried out, in the case of the fixed hearth type, by use of the porter bar and balance weight, whilst for the bogie type, " Somers " patent lifting tongs are used. The ingots are normally manipulated under the presses by means of turning gear and burden chain controlled from the crane cage.

Re-heating Furnaces

All furnaces are located in the furnace bay, the re-heating furnaces discharging into the forge bay, whilst those of the heat treatment type discharge into the heat treatment bay.

The refractory bricks used for furnace construction are of the highest quality and where possibly hot face insulation bricks are used in the interests of fuel economy.

The following re-heating furnaces, all of which serve the two forging presses, have been provided by Priest Furnaces, Ltd. :—

(*a*) Six bogie hearth type, three having effective

View of upper floor of pump house showing hydraulic pump units.

dimensions of 14 ft. long × 7 ft. wide × 7 ft. high, the remainder being 15 ft. × 7 ft. 3 in. × 7 ft. The latter three have been transferred from the Company's existing facilities.

(*b*) Five fixed hearth type, three being 14 ft. × 7 ft. × 7 ft., the other two being 12 ft. × 6 ft. × 6 ft.

Space has been provided within the main scheme for the installation of three further re-heating furnaces.

These furnaces are of the reversing regenerative type, both air and gas being preheated. The air passes through regenerators and the gas through a tubular metallic needle type recuperator. It will be appreciated that this system of heat recovery gives the conditions necessary for rapid and satisfactory heating of the stock. The reversing equipment is of particular interest. The air/waste-gas valve, which is of the rotary type, has a water cooled paddle and drum, which enables it to deal with high temperature exhaust gases with a minimum leakage. Gas reversal is effected by means of water sealed dipper type valves. The functioning of this gear is completely automatic, the sequence being electrically controlled to take place at pre-determined intervals. From the reversing unit, gas is led to the furnace through lagged mains terminating at the combustion ports, to which air is distributed through underground flues. These combustion ports are arranged alternately to direct the products of combustion over and under the stock. The furnaces are of robust construction, the side and back walls being enclosed in mild steel casing, and the fronts and doors are constructed in hematite iron castings. All re-heating furnaces have a maximum working temperature of 1,350° C., the temperature being controlled within the limits of ± 10° C. from 550° C. upwards.

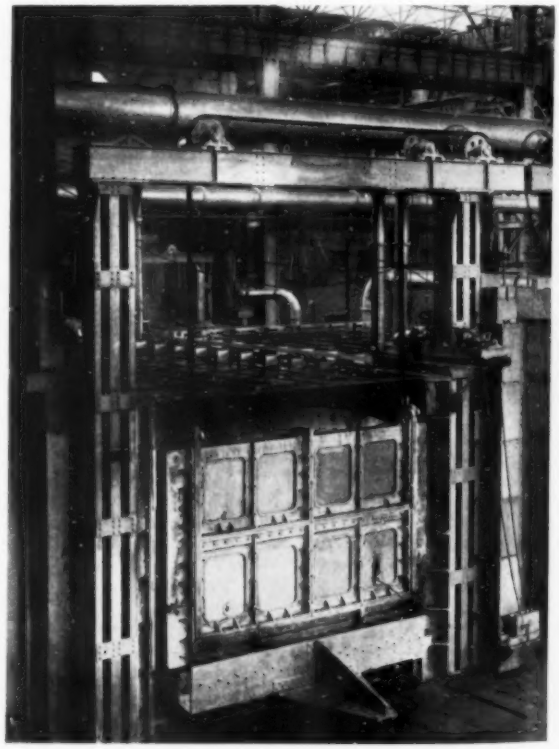
Heat Treatment Furnaces

The nine furnaces which comprise the heat treatment section are all of the bogie hearth type, and comprise the following :—

2—40 ft. long × 14 ft. wide × 9 ft. high.
2—30 ft. long × 12 ft. wide × 9 ft. high.
1—20 ft. long × 10 ft. wide × 9 ft. high.
3—15 ft. long × 9 ft. wide × 6 ft. 7 in. high, and
1—30 ft. long × 12 ft. wide × 7 ft. 6 in. high.

The five larger furnaces, which are of Priest Furnaces Ltd. manufacture, resemble in many respects the reheating furnaces, but are of the air regenerative type with the combustion arrangements and reversing equipment similar. In this case, however, with lower maximum temperature requirements, pre-heating of the gas is unnecessary. The bogies, which are constructed from rolled steel sections, are carried on steel wheels and stub axles, and have an insulated refractory hearth. Particular attention has been given to the sealing arrangements to prevent ingress of atmospheric air or the escape of exhaust gases. Sand seals are arranged along the full length of each side and a special bridge construction is adopted in the furnace back wall to allow an extension of the bogie to pass beneath it and provide a means of sealing at this point. The maximum working temperature of the Priest heat treatment furnaces is 1,250° C.

Of particular interest in the heat treatment furnaces are the recirculation type designed and installed by Brayshaw Furnaces and Tools, Ltd. One of these furnaces, having a bogie area 30 ft. long and 12 ft. wide,



View of Priest heat-treatment furnace—
40 ft. long × 14 ft. wide × 9 ft. high.

with a loading capacity of 45 tons, is the largest of its kind in the country.

Three tempering furnaces have been installed for precise temperature treatments, within a range of 100° to 750° C., of the large and varied loads produced in the forge. The system of heating has been designed to overcome the difficulties experienced at low temperatures in normal types of furnaces, namely, the slow heating rate, the inequalities of temperature distribution resulting from local radiation and the slow moving convection currents of the gases used.

These furnaces differ fundamentally from the usual type in that instead of burners being used for heating the work chamber, the heat is generated in a combustion unit which is entirely separate from the furnace proper. In order to obtain the extreme accuracies and speed of heating at temperatures from 100° to 750° C. very large columns of hot gases at high velocity are used as the heating medium, and are continuously recirculated by powerful fans through the furnace chamber in a closed system of ducting. Control of the furnace temperature is extremely simple since it is only necessary to regulate the temperature of this single body of main circulating gases by adding to them the small quantities of fresh gases being burnt in the external combustion chamber.

View of three Priest reheating furnaces.

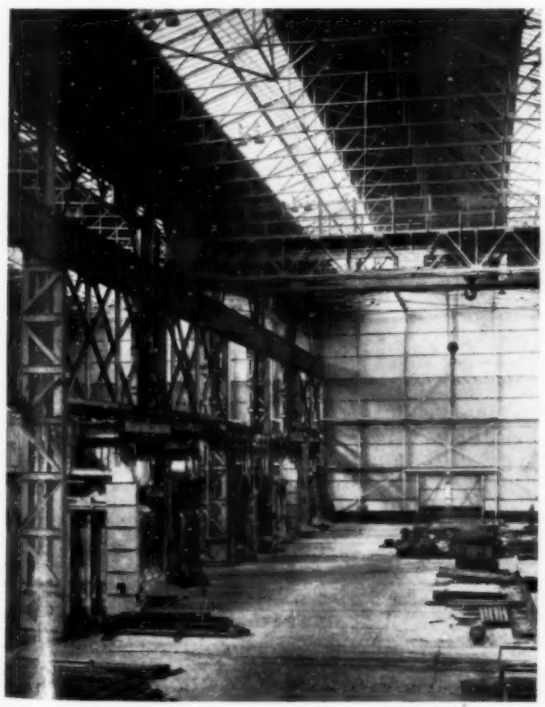
A further advantage of this system is that the load cannot be heated to a temperature exceeding that of the gases in circulation, the volume of which is such that the heat absorbed by the load represents but a small fraction of the total heat potential being circulated. The result is that the load in the furnace is completely and evenly heated to a temperature which can be controlled to the fine limits of a ± 3° C. This system of heating as applied to the large 30 ft. × 12 ft. furnace is such that the high velocity gases are recirculated from wall to wall across the furnace chamber, the direction of the flow of gases being automatically reversed at pre-determined intervals in order to apply the heat to the load from each side in turn.

The furnace combustion chamber has been designed for use with either " Town " gas (500 B.T.U's/cu. ft.) or coke producer gas (132 B.T.U's/cu. ft.) together with low pressure air, and is divided into two smaller combustion units each being separately fired and provided with a permanently lit pilot flame. For very low temperature work the furnace can be heated from one combustion unit only.

The furnaces are substantially built for heavy duty and are well insulated. Circulating fans of the centrifugal type are employed. The furnace chamber works under a slight positive pressure and seals are provided on the doors and bogies to prevent loss of circulating gases.

The whole furnace combustion system is adequately safeguarded against accidental damage by a series of safety devices which work in conjunction with an electro-magnetic gas shut-off valve. These safety devices are wired up to a self-contained floor mounting panel complete with alarm circuits, starting switches, etc., and should the gas supply be cut off for any reason warning lights and an alarm bell bring the fault to the notice of the operator.

The two smaller recirculation type furnaces of bogie hearth area 9 ft. wide × 15 ft. long, with a maximum loading capacity of 30 tons, use the same principle of



General view of heat-treatment bay showing fronts of heat-treatment furnaces.

General view showing three Brayshaw tempering furnaces and one hardening furnace. (The hardening furnace is on the extreme right.)

recirculation and in general, embody the same features of construction as the large 30 ft. furnace. As distinct from the crossflow type of heat flow, however, these furnaces are of a more simple downflow type without reversing gear, the hot gases entering the furnace chamber through the furnace arch and returning for recirculation through ports at each side of the furnace.

Operating in conjunction with, and of identical size to the two 15ft. tempering furnaces is a Brayshaw hardening furnace, designed to operate at temperatures from 550° to 1,250° C. This furnace has been installed for general purpose work at maximum efficiency over a wide temperature range. The furnace is direct fired by two separate sets of burners, one set firing under the furnace arch, the other set arranged to fire through ports in the bogie hearth, with independent adjustment between top and bottom heating. Recuperation is included for both air and gas, with recuperators of the metallic needle type, waste flue gases being exhausted to atmosphere by a positive motor driven exhaust fan. All hot gas and air pipes are adequately lagged to maintain the recuperated heat up to the burners.

As in the case of the tempering furnaces, an electromagnetic gas shut down valve is included in the mains supply to the furnace to operate in the event of an air supply failure.

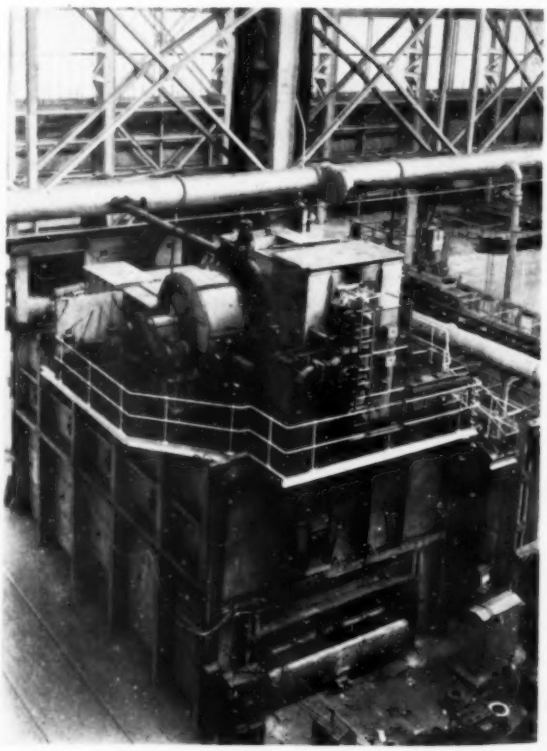
Bogie haulage for both re-heating and heat treatment furnaces is provided for by means of special rack wheels, electrically driven, engaging with pin type racks, which are located centrally below the furnace bogies. Where two bogie type furnaces are in adjacent positions a twin haulage unit is used in which a single electric drive with reduction gearing is located between the furnaces to operate either of the bogies, a system of clutches ensuring that only one may be moved at a time. The haulage units, all of which were supplied by Priest Furnaces, Ltd., are electrically interlocked with the door lifting gear (also electrically operated) to ensure that the door is in the open position prior to charging or withdrawing the bogie.

Gas

Clean gas of a gross calorific value of 132 B.T.U's per cu. ft. is distributed to the furnaces from a 30 in. diameter overhead ring main around the furnace bay at a height of some 28 ft. above floor level, this main being supplied at a pressure of 2½ lb./sq. in. from the Company's own coke producer plant. Pressure in the ring main is maintained at 30 in. W.G. by means of an Electroflo oil-operated gas pressure regulator. The necessary branch pipes are taken off the main at suitable points to each of the re-heating and heat treatment furnaces. Shut-off valves and gas pressure governors are fitted in all branch pipes and the gas is supplied to the furnaces at a pressure of 6 in./8 in. W.G. except in the case of the four Brayshaw heat treatment furnaces, which operate on a pressure of 28 in./30 in. W.G.

Instrumentation

In concluding this description of the furnaces, mention should be made of the instruments which have been installed to ensure efficient and economic working of the twenty furnaces in this shop. The temperature of each furnace is automatically controlled in the following



View on top of large Brayshaw tempering furnace showing in detail the external combustion chambers and circulating fan.

manner. A thermocouple actuates an electronic potentiometer temperature recorder-controller, the output from which is converted into movement of the gas and air valves by means of a regulator. The valves are mechanically linked and are so designed as to give a constant air/gas ratio under all conditions. Furnace pressure control has been fitted on two furnaces to maintain the pressure inside the furnace at hearth level slightly in excess of atmospheric pressure to prevent infiltration of cold air into the furnace and the hot gases being expelled other than through their normal channels. Gas and air flow meters have also been provided, the former, which have been supplied by George Kent, Ltd., recording the gas flow together with the total gas consumption, whilst the latter enable the operator to check the air/gas ratio. Gas and air pressure gauges are also provided. All instrumentation and controls, with the exception of the gas flow meters have been supplied and installed by Messrs. Electroflo Meters, Ltd.

In addition to those forming part of the automatic temperature control, thermocouples are inserted in the furnaces at various points to assist the operator in maintaining equal temperature distribution of the hearth loads. The temperatures are measured on multipoint electronic potentiometric recorders and indicators supplied by Messrs. Honeywell-Brown, Ltd., these being installed in two central pyrometer houses within the forge.

Quenching Facilities

A range of oil and water tanks have been provided in the heat treatment bay for the purpose of quenching forgings during heat treatment. They include :—

2 Vertical Tanks 8 ft. diameter × 54 ft. deep (each of 17,000 gallons capacity); 2 Horizontal Tanks 40 ft. × 12 ft. × 10 ft. deep (each of 30,000 gallons capacity); and 2 smaller horizontal tanks 14 ft. × 9 ft. × 10 ft. deep (of 7,800 gallons capacity)—one of each size being used for oil quenching, the other for water quenching.

The horizontal tanks, which are of welded construction, and manufactured by Messrs. Fawcett Preston & Co., Ltd., are set in concrete pits and for ease of quenching operations the tops of the tanks are three feet above ground level, whilst the cylindrical tanks are completely below ground. The vertical tanks are utilised for the quenching of long forgings, whose length to diameter ratio is high, in order to minimise distortion during hardening.

Circulation for cooling purposes on the water tanks is arranged for by a river water mains supply, the overflow being connected to the main drainage system of the shop. In the case of the oil tanks, centrifugal pumps are employed for circulation purposes on the closed circuit principle. Adequate oil coolers are incorporated in the oil circuits to enable the temperature of the oil to be kept within required limits when quenching is in operation.

The cooling systems for the large horizontal and vertical oil tanks are interconnected, thus enabling both systems to operate on any one tank if a rapid rate of cooling is desired, whilst that for the smaller tank is arranged independently. The pipework and oil circulating systems were supplied and installed by Messrs. William Press & Son, Ltd.

View of quenching tanks in heat-treatment bay.

Electrical Installation

Incoming supply is taken from the main sub-station of the works by a feeder cable to the forge sub-station at a pressure of 11,200 volts, 3 phase, 50 cycles, where this is connected through oil circuit breakers of 150 mVA capacity of A. Reyrolle & Co., Ltd. manufacture, to two 1,500 kVA 11·2/3·3 kV Oil Natural cooled transformers, supplied by C. A. Parsons & Co. The secondaries of the transformers are connected to a 3·3 kV switchboard manufactured by Messrs. Switchgear & Cowan, Ltd. Each of the five pump motors is fed from an individual circuit breaker on this board.

The 3·3 kV supply is then reduced to 400 volts, the standard for all motors in the shop, in two Parsons 500 kVA O.N. cooled transformers for distribution to the various points in the building through a Crompton Parkinson, Ltd. switchboard.

A D.C. supply of 230 volts for the cranes is obtained through a G.E.C. 500 kW mercury arc rectifier unit.

All cabling, the greater part of which is required for the furnace motors, is of British Insulated Callender Cables, Ltd., manufacture and is carried in underground trenches. The electrical installation has been carried out by F. H. Wheeler (Sheffield) Ltd., with the assistance of the Company's own staff.

The main lighting for the forge building is of the latest type used, and is a combination of mercury discharge and incandescent filament lamps with suitable reflectors, all of Benjamin manufacture, calculated to give 9/10 lumens per sq. ft. at the working plane. In the hydraulic pump house and sub-station building, however, fluorescent lighting has been employed.

Compressed Air and Oxygen

A 2 in. diameter compressed air main supplying air at a pressure of 100 lb./sq. in. serves the three main bays, connections being taken off at numerous points throughout the shop for such operations as scale-blowing, chipping and grinding whilst an oxygen supply line has been installed by the British Oxygen Co., Ltd., in the stock bay for ingot torching purposes.

Water Service

In addition to the hydraulic service, water is required for quenching and oil cooling purposes in the heat treatment bay and also for cooling purposes for the exhaust and blowing fans and the air and gas reversing valves on the furnaces. Both clean and river water are employed, the former being used for the accumulator plant, the presses and where small bore pipes are installed, whilst the latter is used for oil cooling and quenching purposes and for the cooling of air and gas reversing valves. The complete water service has been installed by William Press & Son, Ltd.

Copper on the Screen

MEMBERS of the newly formed Refrigeration Serviceman's Association were fortunate through the enterprise of their Hon. General Secretary in securing a first showing of the three new sound films produced by the Yorkshire Copper Works, Ltd., Leeds, on Friday the 12th of October, in the Lecture Theatre of the North Western Gas Board, at Radiant House, Bold Street, Liverpool. These films are entitled: "'Yorkshire' in the Making"; "The 'Yorkshire' Way"; and "'Yorkshire' on Special Service."

A short talk by Mr. C. F. Middleton, the Assistant Sales Manager of the Company, preceded the showing, and dealt in an instructive and interesting manner with the history and growth of the works, and with many difficulties that had to be overcome in providing suitable tubes and fittings, for special applications in many industries.

"'Yorkshire' in the Making," shows the Victorian plumber who made a good job with lead pipes and wiped joints, and sharply contrasts the old method with the new as exemplified in the use of copper tubes in a light gauge, and the special solder fittings which are a feature of the Company's products rapidly gaining popularity in many spheres, both industrial and domestic. Not only does this film deal in detailed manner with the production of tubes in copper and alloys, but it also introduces new developments, new plant and equipment, processing and testing methods of absorbing interest to the layman as well as to the specialist.

In "The 'Yorkshire' Way," the installation of Yorkshire tube and appropriate fittings are seen executed in a number of the principal applications. Installation of hot and cold water services, and waste systems are dealt with thoroughly, with special emphasis on the making of joints with some of the many different varieties of fittings. A section is also devoted to the forming and laying of coils, using "Yorcalon" (long length) copper tubes for panel or radiant heating.

Special salt water fittings for hot and cold salt water pipe-lines to cabins, bathrooms, galleys, and drying rooms on board ship, and "Yorkshire" high duty fittings—designed for pipe lines operating at high pressures and/or high temperatures—for such purposes as steam, feed, blow-down and similar boiler services and for high pressure hydraulic and compressed air-lines are featured in "'Yorkshire' on Special Service." Fittings for lines of fractional outside diameters are shown on refrigeration plant, for general engineering purposes and on Calor gas and water pipe-lines in caravans. The last-named application shows how small outside diameter pipe-lines can be rapidly assembled on mass production lines, in the caravan production workshop.

The talk and the films were well received and the general verdict of the 50 members present was that it was both very instructive, and of great general interest. Light refreshments were then served and a full range of tubes and fittings were laid out for inspection, together with appropriate available literature. These films will do much to interest all engineers using tubes and requiring an easy and neat system of jointing.

O.E.E.C. Takes Steps To Improve Aluminum Production

A RECENT decision of the Council of the Organisation for European Economic Co-operation invites Member countries to take steps to provide increased supplies of electric power for the production of aluminium. In 1950, Western Europe could only use some 45% of her production capacity for aluminium, vital for defence needs and as a substitute for scarce heavy metals. This state of affairs arose from the shortage of electric power supplies which prevented producers from making full use of existing plants. The situation improved in 1951, owing to the abundant rainfall which permitted hydro-electric power stations to increase their production of electricity, and it appears from first estimates that during this year three-quarters of available production capacity has been used. Nevertheless, production is still liable to be affected by serious power shortages under unfavourable weather conditions. If total production capacity could be used, Member countries of the Organisation would be able to provide from their own resources a great part of their 1952–53 consumption requirements, estimated at 500,000 tons.

For this reason, the O.E.E.C. Council has decided to address an urgent appeal to Member countries asking them to take all measures in their power to permit aluminium factories to work at full capacity by providing them with sufficient power at economic rates. To obtain this result, Member countries are asked to ensure that power produced by power stations set up specially to serve aluminium producers should not be put to other uses, and also to ensure that plants not possessing special power stations should receive regular and sufficient quantities of electric current.

In the meantime, the Non-Ferrous Metals Committee and the Electricity Committee of the Organisation will keep close watch on the progress of the production of aluminium in Member countries and developments affecting power supplies for the industry.

Production Engineering Research Association

Review of Year's Activities

By Dr. D. F. Galloway, Wh.Sch., M.I.Mech.E., M.I.Prod.E., M.I.I.A., A.M.I.E.E., B.Sc.Hons., M.Inst.Pet.

With a growing realisation of the necessity for improving productivity has come an increased demand for production engineering research from many different sections of industry. The author discusses some aspects of the progress which has been made during the past year by the Production Engineering Research Association of Great Britain, and indicates the lines on which it is hoped to expand its activities.

DURING the past year the heavy burden thrown on industry by the need to expand arms production, increase exports and maintain living standards at home, has stimulated the demand for more production engineering research from many different sections of industry.

The writer visited the U.S.A. during the year to study American production engineering research and to promote an interchange of ideas on research techniques. Research facilities were inspected in about thirty different organisations, and convincing evidence was available that both the United States Government and industry have determined to increase American productivity by expending vast sums of money on research into a wide variety of production processes. The accelerating pace of American research underlines the importance of expanding Britain's production engineering research as quickly as possible.

Sir William Stanier, F.R.S., who was recently elected President of PERA, examining a set-up at PERA for investigating the function and lubrication of slideways.

PERA's Close Ties with Industry

To ensure that existing research facilities are utilised to the best advantage, PERA is maintaining very close contact with industry, and last year several Advisory Panels representing various sections of industry held their first meetings to propose for research by PERA the most urgent problems of the many different types of firm in PERA membership.

Advisory Panels which have met include those for: Road Vehicle and Accessory Manufacturers; Gauge, Tool and Instrument Manufacturers; Special Machinery Manufacturers; Electrical Equipment Manufacturers; Engine and Turbine Manufacturers; Cutting Tool, Abrasive and Metal Manufacturers; Aircraft, Pump, Compressor and Refrigerator Manufacturers; and Locomotive and Rolling Stock Manufacturers.

Recommendations from each Panel are considered by the Technical Policy Committee, who undertake the task of allocating research capacity and priorities to the subjects proposed for research. Some of the many proposals made by Advisory Panels are set out below:

ROAD VEHICLE AND ACCESSORY MANUFACTURERS' ADVISORY PANEL

Development of techniques for impact extrusion of ferrous and non-ferrous metals;
Determination of most suitable materials for thread rolls;
Relative merits of different pretreatment processes in metal finishing;
Development of suitable procedure for barrel tumbling and other finishing operations;
Assembly methods and jointing processes;
Reduction of hand-work in all branches of manufacture;
Machining problems associated with leaded steels;
Economy in use of carbide tools;
Methods of dressing grinding wheels.

GAUGE, TOOL AND INSTRUMENT MANUFACTURERS' ADVISORY PANEL

Research into die hobbing methods;
Standardisation of grinding allowances;
General investigation of performance of cemented carbide tools;
Fine boring methods for mild steel;

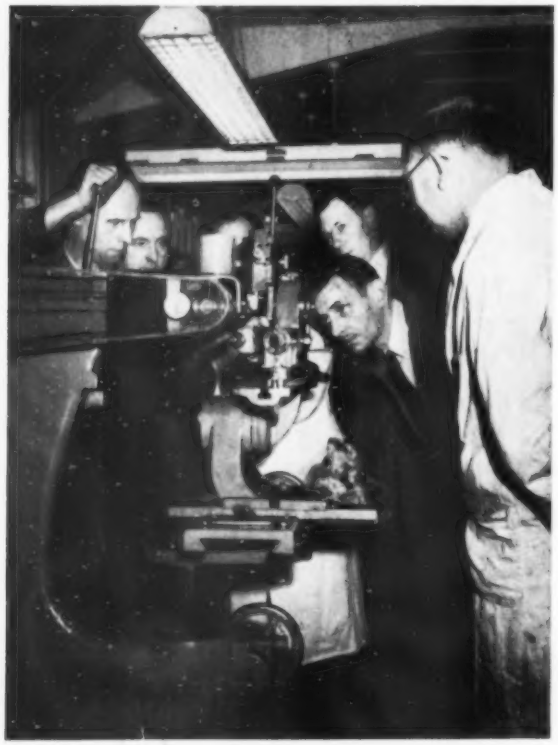
Economical production of cylindrical components to close limits of accuracy ;
Surface hardness of lapped and polished surfaces ;
Production of rolling bearings for instruments and small machine tools ;
Elimination of grinding cracks in hardened tools ;
Grouping and classification of tool steels.

SPECIAL MACHINERY MANUFACTURERS' ADVISORY PANEL

Lubrication of presses, high-speed machinery and machine tools ;
Increasing the life of protective coatings applied to die castings ;
Development of the precision investment casting process for large components ;
Economical production of high-quality components ;
General investigation into the machinability of such materials as D.T.D. 683 ;
High-speed machining of interrupted surfaces.

ELECTRICAL EQUIPMENT MANUFACTURERS' ADVISORY PANEL

Increasing life of tools used in production of high silicon steel (Stalloy) stampings ;
Press-working of thin sheets with special reference to to elimination of cracking ;
Further industrial development of powder metallurgy ;
Impact extrusion of copper and steel ;
De-skilling and speeding-up mould cavity polishing methods ;
Moulding methods for insulating materials ;



Up-to-date tool grinding techniques being demonstrated to industrial personnel in PERA centralized tool grinding bay.

General investigation of methods of preventing corrosion during manufacture ;
Rationalisation of de-burring procedures ;
Machinability of boron copper and recently developed permanent magnet alloys ;
Machining methods for commutators and laminated armatures ;
Machining of plastic materials.

ENGINE AND TURBINE MANUFACTURERS' ADVISORY PANEL

Determination of blank diameters when rolling unified screw threads ;
Increasing roll life when thread rolling various metals ;
Deep drawing of heat-resisting nickel alloys ;
Abrasive cleaning of small bore pipes ;
Development of standard tests for ascertaining grinding wheel characteristics ;
Machinability of the Nimonic alloys ;
High-speed machining of cast iron ;
Increasing die life when screwing high strength alloys ;
Diamond turning.

Membership

During the period under review there has been an encouraging increase in membership to over 300 firms. After considering further expansion of the Association based upon the potential membership of engineering firms in Britain and the Commonwealth, the Association has purchased further land adjoining the present site to provide space for additional buildings. Preliminary plans have been completed for a new permanent building with a floor space of about 50,000 sq. ft.

Increasing support is the key to the future development of the Association, and an open invitation has always been extended to non-members to visit the Association's Melton Mowbray headquarters. Considerable interest in PERA has been evoked at special meetings of Directors of non-member-firms in various centres. Expansion of the Association's resources is particularly important in view of the urgency of many of the production problems proposed for research by the Advisory Panels representing different sections of industry. In a recent message to members, Sir William Stanier, F.R.S., elected President of the Association at the Sixth Annual General Meeting in July, referred to the Association's further expansion in the following words :

> " All the forces of technology are being marshalled on a National scale to find faster and cheaper ways of making British products, and it rests with Industry and the Nation to determine the rate of growth of this endeavour."

Information Services

Technical Enquiry Service. Very heavy demands have been made on all information services throughout the year, and over 650 requests for technical assistance on a wide variety of problems have been received from member-firms. Output has been increased and production costs reduced following assistance received by members, and many expressions of appreciation of this service have been received. Problems dealt with have embraced almost every branch of production engineering, including, for example, the assembly of various types of equipment, induction heating techniques, inspection, factory layout, investigating machine failures, working

conditions, cold extrusion, finishing problems, hobbing, preventive maintenance, trepanning, extrusion, etc.

The many hundreds of enquiries successfully answered have made it possible to assess the savings in production costs on the operations concerned, but the substantial savings in Directors' and Executives' time are equally important, though more difficult to calculate. An outstanding merit of this service has been its ability to relieve managements of many problems and snags to which they have not really the time to devote adequate attention.

Information on developments abroad arrives regularly at PERA and constant contact is maintained with representatives in America and on the continent.

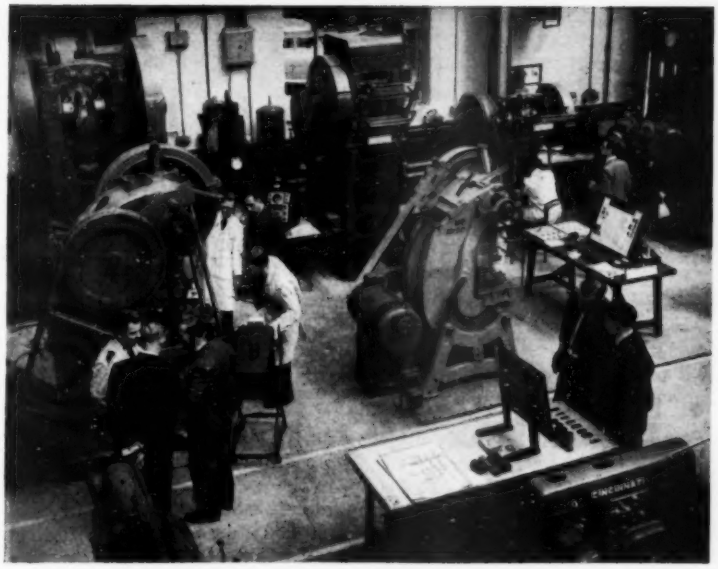
Library Services. The production engineering library which is being built up at PERA headquarters is one of the many sources of information open to PERA when answering technical enquiries. The library is expanding rapidly and at present contains more than 60,000 items of trade and technical literature. A large number of books and back numbers of periodicals have been acquired during the past year, and the library has been nearly doubled in size to accommodate the increasing collection.

Production Engineering Abstracts. The recent publication of the 12,000th abstract in PERA Bulletin is an indication of the immense volume of information which has been referred to in these abstracts. The Bulletin summarises the most important articles on production practice in 320 journals published in different countries and thus assists firms in keeping abreast of production developments with the minimum effort and expense. A few minutes perusal of each monthly Bulletin keeps personnel informed of production developments. Use of the Bulletin results in large savings in time, as significant developments can be studied without first making a long search through the original publications. Classification of the abstracts under general subject headings further assists in concentrating the reader's attention on subjects of direct interest. Abstracts have created a heavy demand for the original articles and to date more than 50,000 articles on a wide variety of subjects have been requested by firms.

Firms often substantially increase Bulletin circulation as experience is gained of its practical value. One firm requested six copies on first joining the Association, but in a few months this increased to 60. Another large firm uses nearly 90 copies per month. The Bulletin now has a total circulation of nearly 3,000 copies per month.

Member Liaison

The value of member liaison visits in securing effective utilisation of all PERA services, and in promoting higher efficiency in individual firms, has again been amply demonstrated. These visits permit production problems to be studied at the production site and ensure that recommendations take account of the particular conditions in the factory concerned. Higher production efficiency has often been achieved by simple changes in method or layout. Usually, member liaison comprises a tour of a works, meetings with departmental heads, foremen, etc., and discussions of problems with workshop production personnel.



Executives of engineering firms discussing with PERA engineers various metal forming problems being investigated by PERA.

Training Courses and Conferences

The short refresher courses in which hundreds of supervisors, managers, etc., have already participated have been one of the most successful of the various techniques developed by PERA for securing the widest application of research results. In these courses results are presented in a form which facilitates their application in industry, and practical demonstrations of research in progress are designed to secure the application of results as they become available.

The most up-to-date cutting tool grinding techniques are being demonstrated in a centralised tool and cutter grinding section as each stage of PERA's metal cutting research programme is completed.

There continues to be a heavy demand from member-firms for participation in the six month courses for young engineers, special courses of instruction and training in production engineering techniques for personnel from individual firms, and refresher courses for foremen and other workshop personnel. New courses for personnel from firms varying in size and type of manufacture have been held recently.

Research Department

Equipment and Buildings

During the year 25 machines, instruments, etc., have been installed, and an additional 30 major items of equipment are on order ; some new equipment has been received under the E.C.A. Technical Assistance Scheme. The Association's research capacity has also been augmented by automatic machines loaned by member-firms for use in an extensive series of turning tests.

More than 70 pieces of research equipment have been designed and made in PERA workshops, including high speed tapping fixtures to expedite various large scale

tapping investigations, dynamometers for press working and metal cutting and a high speed small-hole drilling machine incorporating electronic control devices and measuring instruments.

Temporary buildings of about 5,000 sq. ft. floor area have been erected, and the conversion of existing outbuildings into a workshop has been completed.

Press Working

Present practice in many press operations is largely based on inadequate basic data, and research techniques based on precise measurement of all variables are being developed to provide industry with reliable data.

Bend Allowances. PERA has completed a preliminary investigation into bend allowances for sheet materials, and the test results show that methods commonly used for calculating bend allowances are often inaccurate. The principal object of the first stage of PERA's practical research into this subject was the determination, for various materials, of an accurate formula independent of the location and shape of the neutral line, and tests carried out on an open-fronted crank press and on a rubber die press. The research has now been widened in scope to include the determination of bend allowances for mild steel, alloy steel, brass, copper and aluminium sheet in the soft and full hard tempers, in thicknesses between 0·010 in. and 0·160 in.

Blanking and Piercing. Clearance between punch and die in blanking tools is fixed by arbitrary rules which vary from factory to factory, and PERA is therefore investigating the effect of different values of die clearance on hole shape, size, finish, etc., and on punch load and stripping force. A preliminary investigation has already been completed, and as the results of this investigation confirmed the need for more extensive information on blanking and piercing, PERA's research on this subject has been extended to include mild steel, alloy steel, brass, copper, aluminium sheet and silicon iron in thicknesses between 0·010 in. and 0·375 in.

Deep Drawing. Tests are in progress to determine the effect of punch radius and drawing radius on maximum reduction in deep drawing operations, and the results should establish the most suitable punch and drawing radii for the economical production of deep drawn parts in various metals. The relative merits of a number of drawing lubricants are also being investigated.

Thread Rolling. An investigation is being made of the relative rollability of ferrous and non-ferrous materials, and of the effect of penetration rate on rollability. Blank diameters for rolling unified screw threads are also being determined.

Experience has shown that die life may vary considerably when rolling materials with similar physical properties, and investigations of the flow characteristics of different materials under conditions of plastic deformation is an essential requirement in this field. The scope for further researches includes investigations of such factors as work-hardening properties of materials, speed of rolling, lubricants, die materials, and heat treatment.

Impact Extrusion. A significant increase in productivity would result from wider application of the impact extrusion process in Britain, and recently PERA has been preparing for research into this process in order that information relating to metal flow, tool wear, extrusion resistance, die production, etc., can be made generally available.

Metal Cutting Investigations

Drilling. Extensive drilling tests carried out by PERA have shown how the overall economic efficiency of drilling operations can be greatly increased by applying the results of these investigations to the selection of drilling conditions, the grinding and inspection of drills, the selection and application of cutting fluids, the selection and efficient use of drilling machines, drill holding devices, etc.

Turning. In drilling operations the cutting tool takes a roughing cut only, but many other machining operations involve roughing and finishing cuts, and it is desirable to separate all practical tests into two sections having different criteria for assessing performance, as rough machining and finishing machining operations have very different objectives. Tests are in progress to determine the effect of lathe tool finish on tool life during rough turning, and on the surface finish of the workpiece and tool life during finish turning. Automatic machine tools are being employed in this investigation, the machined components being supplied to firms for use in manufacture in order to conserve materials.

Grinding. Grinding research also figures prominently in the current research programme, and an investigation is in progress to determine the way in which wheel performance and workpiece surface finish are affected by wheel grade, grinding speeds and feeds, traverse and in-feed rates of dressing diamond, and method of application of the cutting fluid. The criteria by which grinding wheel performance must be judged include workpiece surface finish and dimensional accuracy, grinding wheel wear, and rate of production of finished surface.

Tapping. The extent of research necessary to secure authoritative data for application in workshops may be judged from the fact that in a recent tapping investigation, for example, 10,000 tap measurements were made in addition to the tapping of approximately 300,000 holes. Tests have been made to determine the effect of core hole diameter on tapping torque, and substantial progress has been made in an extensive series of life and performance tests on various sizes of tap. Automatic equipment has been made to expedite this work and to ensure that the tests are closely related to factory conditions.

Cutting Fluids

The choice of a suitable cutting fluid and its method of application are important factors in machining operations. Following research into the effect of soluble cutting oils on the performance of cemented carbide tools and high-speed lathe tools and drills, the effect of these fluids in milling and grinding operations have been investigated. The general properties and performance of the oils based on the results obtained in all tests have been summarised in a final report on these investigations. The results of the grinding tests showed that the same oils gave the best performance on all the materials machined, and one of these oils gave good results more frequently than the remainder in each type of test.

Machine Tools

Further progress has been made with the Association's general machine tool research, and investigations have been or are being made of several types of machine tools, such as lathes, drilling machines, grinding machines, etc. The geometrical accuracy of angular contact rolling bearings has been investigated and the bearings have

been fitted into a special machine tool to determine the accuracy of work produced.

Vibration in machine tools arises from unbalanced forces in rotating parts, faulty gearing, etc., and from the cutting action itself. In operations like milling, vibration is caused by the intermittent nature of the cut, but the causes of vibration in a continuous operation such as turning are not yet completely understood. However, as a result of recent work into the nature of the cutting action, lines on which an answer should be sought have been discovered, and future work will, it is hoped, remove the necessity for trial and error in reducing vibration. Special equipment has been built by PERA for separating out the components of vibration and tracking down those parts causing trouble.

Special Investigations

In addition to the general researches undertaken by the Research Department, special problems are sometimes investigated on behalf of individual firms, especially when it is considered that the problem will provide a solution of general interest or will assist other members with similar problems. These investigations have often produced considerable economic gains in the firms concerned.

Future Activities

As PERA's resources and facilities increase, research is being initiated into many of industry's most difficult production problems. Although practical investigations have so far been mainly associated with metal forming and metal cutting, investigations of problems relating to methods of assembly, heat treatment, inspection and measurement, impact extrusion, manipulation of plastics, forging, rolling and other production activities are to be undertaken in accordance with the needs of member-firms.

British Rolling Mill For Norway

Against strong German competition, Davy & United Engineering Co., Ltd., of Sheffield, have secured a further large order for rolling mill equipment from the Norwegian steel company, A/S Norsk Jernverk. This order for a Morgan Combination Merchant Bar, Wire Rod and Strip Mill brings the total value of business now being handled by Davy-United for A/S Norsk Jernverk to over £2 million and lifts the total of export orders now on the Sheffield Company's books to more than £5 million.

The Morgan Mill plant will be complementary to the Davy-United Blooming, Slabbing and Section Mill plant ordered by A/S Norsk Jernverk 14 months ago and will be installed as an essential additional part of the new integrated iron and steel works now being established by that Company in Northern Norway, at Mo i Rana, 25 miles south of the Arctic Circle. The new plant will be built by Davy-United to the designs of Morgan Construction Company of Worcester, Mass., U.S.A., specialists in the engineering of mechanised high-production continuous mills of the type called for under this contract, and with whom Davy-United have worked in close association for more than 30 years.

The Morgan Mill will consist of a 7-stand roughing train complete with two vertical edging mills, a 4-stand intermediate train with two further vertical edging mills, a 2-stand looping train with skew tables and repeaters and a 6-stand rod finishing train. All roll stands will be equipped with Morgoil roll neck bearings. A host of auxiliary plant including furnaces, automatic shearing, coiling and handling equipment will also be supplied. Over two thousand tons of finished mill machinery alone will be involved. The Morgan Mill will produce coiled strip from 25 mm. to 265 mm. wide, merchant rounds, merchant flats, angles, channels, tees, beams and wire rod in coils from 5 mm. to 9·5 mm., starting from billets and slabs from 50 mm. square up to 65 mm. × 265 mm. It will be capable of rolling speeds of over 4,000 feet per minute, and will be designed for double strand rolling. Initially the mill will be required to produce 80,000 tons annually but has capacity for an ultimate annual output of 150,000 tons.

It is interesting to note that the new works at Mo i Rana will eventually be the largest steel works in the world in which iron will be produced by electric smelting instead of by the conventional blast furnace, a fact which is particularly applicable in Norway with its vast accessible resources of cheap water power. The works in fact will be the realisation of plans of many years' standing to develop an enlarged steel industry in Norway based on her own natural assets in the shape of local ores and hydro-electric power.

Inter-Commonwealth Post-Graduate Scholarships in Science

The Royal Society Empire Scientific Conference and the British Commonwealth Scientific Official Conference in 1946 recommended the preparation of a list of post-graduate scholarships available for scientific study within the Commonwealth. The task of compiling the list was assigned to the British Commonwealth of Nations Scientific Liaison Offices in London.

When B.C.S.O. (London) opened in 1948 consideration was given to implementation of the recommendation. Thanks to the generous co-operation of Universities, Institutions and Government departments throughout the Commonwealth the publication "Inter-Commonwealth Post-graduate Scholarships in Science" has now been completed. Since the main objective of the list is to encourage the movement of scientists within the Commonwealth, only those awards open to members of at least one Commonwealth country or Colony other than the awarding one have been included.

The entries are set out in tabular form showing, in addition to the names of the scholarships and the agencies awarding them, details of the fields of study, where tenable, duration and value, closing dates for applications and the addresses to which these should be sent. There are more than 350 separate entries in the list: many of these cover a number of scholarships so that the total of available awards is much greater.

It is published on behalf of B.C.S.O. (London) by His Majesty's Stationery Office. The price 5/– has been fixed the lowest possible level, having regard to present publishing costs, in an endeavour to bring the document within the reach of University students throughout the Commonwealth.

NEWS AND ANNOUNCEMENTS

Foundrymen's Dinner at Newcastle

THE Newcastle-on-Tyne Branch of the Institute of British Foundrymen held an informal dinner at the Crown Hotel, Newcastle-on-Tyne, on November 2nd last, at which there was a good attendance of members and their ladies. The President of the Branch, Mr. C. Lashly, was in the chair and the principal guests were Mr. Colin Gresty, President of the Institute, and Mrs. Gresty.

Welcoming the members and their ladies, Mr. Lashly said it was a great pleasure to have as guests the President of the Institute and his good lady; he had the pleasure of proposing him as junior vice-president, and at the recent Conference of the Institute, held in Newcastle-on-Tyne, he had seconded his nomination as President. For many years Mr. Gresty had worked unceasingly for the Newcastle branch and its successful progress through these years was due in no small measure to his efforts. Now he had a larger field of influence and Mr. Lashly felt that he was voicing the feelings of all members of the branch when he expressed on their behalf, as well as his own, very best wishes for a successful term of office.

Mr. Gresty, responding, said he felt rather strange being a guest in his own branch, but he thought it a good idea to resume these annual functions which had been in abeyance since before the war. This dinner was the first to be held by the branch for many years and he hoped it would be possible again to make it an annual effort. Commenting on the recent Conference of the Institute he took the opportunity of thanking Mr. and Mrs. Lashly for their great efforts in making that Conference so successful; as an expression of their personal appreciation he asked Mrs. Gresty to present to them a small gift of a travelling clock. Mrs. Lashly, on behalf of Mr. Lashly and herself, made it clear that the real work was done by the Committee, that they had worked together as a team, and the success they believed had been achieved was due entirely to that fact, but they would treasure the gift because of the very happy associations it possessed.

A very interesting entertainment was arranged for the latter part of the evening and the whole effort proved to be most enjoyable.

Extrusion Tool and Die Materials Discussion

As already briefly announced, a General Meeting of the Institute of Metals will be held at The University, Edgbaston, Birmingham 15, at 2-30 p.m., on Thursday, January 3rd, 1952, when there will be an informal discussion on "Tool and Die Materials for the Extrusion of Non-Ferrous Metals and Alloys." The Chair will be taken by Mr. Christopher Smith, Chairman of the Metallurgical Engineering Committee.

This is a new venture on the part of the Institute, and is designed to interest those who are actively concerned in production, both as engineers and metallurgists. If successful, it may lead to an extension of the Institute's activities, which it is felt will be of considerable value to a wider range of members.

After short introductory talks by a user and by a manufacturer of tool and die materials, there will be a general discussion in which those engaged in extrusion operations will be encouraged to state their problems. It is hoped that representatives of extrusion-press makers and steel manufacturers will be present to take part in the discussion and to give advice where possible. Non-members who are interested in extrusion will be welcomed.

On the morning of January 3rd, the President (Professor A. J. Murphy, M.Sc.) has kindly arranged for the new Aitchison Laboratories of the Metallurgy Department at Birmingham University to be open for inspection by members at 10-30 a.m. Tickets of admission to the laboratories are obtainable from the Secretary of the Institute.

Lunch can be provided at the University, (price 3s. 6d.) but those who wish to take advantage of this facility must notify the Secretary by December 15th, sending the necessary remittance.

The Institution of Metallurgists Examinations 1951

THE following candidates has been successful in the examinations of the Institution of Metallurgists.

Fellowship: Morton, G. R. (Coventry).

Associateship: Beishon, R. J.* (Wembley); Bindley, D.* (Allesley); Blackmore, K. G. (Liverpool); Bradley, P. (Aylesbury); Brunner, H.* (London, N.W.2.); Cemm, D. (Lewisham); Cowie, J. (Kilbirnie); Daniel, A. R.* (Morden); Davies, D. (Birmingham); Donaldson, J. (Glasgow); Ford, C. (Glasgow); Giblin, J. F. (St. Helens); Hanson, C. C. (Walsall); Hines, J. (Nuneaton); Langford, S. R. A. (Brockley); Loach, R. M. (Bilston); Lloyd, R. C. (Birmingham); Meade, P. H.* (Wirral); Mills, R. (Streatham Common); Perriton, R. C.* (Worcester Park); Randall, M. W. (Coventry); Shapton, R. W.* (Danygraig); Sheppard, N. F. (Hornsey); Ward E. (Doncaster); and Williams, T. (Ruddington).

Licentiateship: Bretherton, R. G. (Croston); Burgess, N. T. (Merstham); Campbell, J. W. (London, S.E.18); Casling, W. H. (Heston); Chadwick, J. D. (Clapham Common); Fricker, D. J. (Slough); Gregory, P. (Farnborough); Hall, E. G. (Slough); Hawley, J. R. (Leicester); Milligan, A. (Rosyth); Mitra, R. K. (India); Morris, C. (Stoke Gifford); Page, R. J. (Uxbridge); Sykes, E. C. (Palmers Green); Thornton, P. C. (Birmingham); and Utteridge, W. R. (Coventry).

* Election to the appropriate grade of membership deferred until regulations in respect of age and experience will have been complied with.

The Corrosion of Buried Metals Change of Hall for Symposium

As announced in the August issue, a Symposium on the Corrosion of Buried Metals, organised by The Iron and Steel Institute in conjunction with the British Iron and Steel Research Association and the Corrosion Group of the Society of Chemical Industry, will be held on Wednesday, December 12th, 1951. Sir Charles Goodeve, O.B.E., D.Sc., F.R.S., Director of the British Iron and Steel Research Association, will be in the Chair. The sessions will begin at 10-0 a.m. and 2-30 p.m. and will be open to all interested.

It was originally intended to hold the Symposium at the offices of the Iron and Steel Institute but, owing to the large numbers wishing to attend, the meeting place has been changed to the Lecture Theatre of The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2.

There will be no charge for admission but intending participants are requested to complete Part A of a Reply form to be obtained from the Secretary of the Iron and Steel Institute. The papers presented (which deal with both ferrous and non-ferrous metals) will be issued, together with the discussion, as a single bound volume (No. 45 in the Special Report Series of the Iron and Steel Institute) at 15s. (post-free). Orders received before the meeting, if accompanied by a remittance, will be supplied at the reduced rate of 10s. (post-free) and one set of advance papers will be supplied without extra charge.

Symposium on Notch Bar Testing

THE Joint Committee on Materials and their Testing and the Institute of Welding announce a Symposium on Recent Developments in the Notch Bar Testing of Materials and their Relation to Welded Construction, to be held at the Institution of Civil Engineers, Great George Street, London, S.W.1., on Wednesday, December 5th, 1951. The Chairman will be Mr. Howard J. Thompson, President of the Institute of Welding. The papers will be presented by Mr. W. Barr, Mr. G. M. Boyd, Professor Soete, Mrs. C. F. Tipper and Dr. J. H. Van Der Veen. All papers will be preprinted and will be presented by Dr. N. P. Allen as rapporteur. Admission will be by ticket only, obtainable from the Secretaries, Mr. G. Parsloe and Mr. G. H. Ford, 2, Buckingham Palace Gardens, London, S.W.1. Advance copies of the papers will be available on November 21st, and will be distributed to those who ask for them. It is intended that the whole of the proceedings should be published. Those who would like to be called upon to speak in the discussion are invited to send their names to Mr. Parsloe or Mr. Ford. Written contributions to the discussion will also be welcome and should be sent similarly to one of the Secretaries.

Head, Wrightson to Build New Ore Plant

A CONTRACT for the design, fabrication and construction of one of the most important projects in the development plan of the British Iron and Steel Industry has been entrusted to Head, Wrightson & Co., Ltd., Thornaby-on-Tees, by the Appleby-Frodingham Steel Co., Scunthorpe, a branch of the United Steel Companies. Head, Wrightson are to build a new ore preparation plant at Scunthorpe, Lincs, which will comprise screening, fine crushing and sintering equipment to deal with the unique problems encountered in treating low-grade British ores from Lincolnshire and Northamptonshire. The plant, which will treat three and three-quarter million tons per annum, will incorporate all the latest British and American technical development and will, therefore, be the most modern of its kind in the world.

John Harper & Co., Ltd.

THE old established firm of John Harper & Co., Ltd., Albion Works, Willenhall, producers of grey iron and Harper-Meehanite castings, have recently completed the purchase of the foundry known as St. James Works, Poole, Dorset, previously operated by Poole Foundry, Ltd. When the necessary re-organisation is completed the foundry will produce a substantial tonnage of castings which will help to meet the demand for "Harper" castings and "Harper" Housewares. In each of these fields of work the major proportion of output is allocated to Government defence work and hard currency exports. One of the main activities of the Willenhall Foundry is the production of castings and domestic hardware which are exported direct to the United States.

Institution of Metallurgists' Refresher Course

THE theme of this year's Institution of Metallurgists' Refresher Course, held at Ashorne Hill from October 26th to 28th, was the Joining of Metals. Professor O'Neill opened the Proceedings on the Friday evening with a paper on "The Metallurgical Principles of Joining of Metals," and Saturday was occupied by a series of papers dealing with the metallurgy of particular joining operations. "The Metallurgy of Soldering and Brazing" was dealt with by Dr. J. C. Chaston; "The Metallurgy of Welding Non-Ferrous Metals" by Mr. W. K. B. Marshall; "The Metallurgy of Welding Carbon and Low Alloy Steels" by Dr. L. Reeve; and "The Metallurgy of Welding Austenitic Steels" by Mr. F. H. Keating. Mr. Keating's paper was presented, in his absence, by Dr. A. J. P. Tucker. The Course concluded on the Sunday morning with a paper by Mr. J. G. Ball on "The Testing of Joints."

Annual Luncheon

THE first Annual Luncheon of the Institution of Metallurgists was held in the Lancaster Room of the Savoy Hotel, London, on Wednesday, November 7th, 1951. The toast "The Institution of Metallurgists" was proposed by Sir Ben Lockspeiser, K.C.B., F.R.S., and the President, Dr. C. J. Smithells, M.C., responded. Dr. Smithells also welcomed the guests of the Institution, who included representatives of many other kindred societies. Sir Walter Womersley, Bt., P.C., J.P., suitably responded on behalf of the guests.

Welding Fault Chart

THE British Welding Research Association has now published an illustrated wall chart of approximately 3 ft. by 2 ft. with 37 half-tone illustrations indicating common faults that can occur in the metal arc welding of steel. The chart is printed in two colours and is mounted on a very strong backing board suitable for direct mounting to the walls of welding shops, offices, etc. Copies of this wall chart, entitled, "Faults in Arc Welds," are obtainable from the Publications Department, British Welding Research Association, 29, Park Crescent, London, W.1., price 7s. 6d. each, post free.

Patent Office Library Hours

IT has been decided to continue the extended hours of opening of the Patent Office Library at 25, Southampton Buildings, Chancery Lane, W.C.2., until December 28th, 1951. The hours are 10 a.m. to 9 p.m. Monday to Friday and 10 a.m. to 5 p.m. Saturday.

Personal News

THE British Thomson-Houston Co., Ltd., announces that MR. C. A. HALL, M.C., B.Sc., A.M.I.E.E., has relinquished his position as Manager of the Industrial Motor Sales Department, and has joined the Secretariat of The British Electrical and Allied Manufacturers' Association. MR. R. G. A. DIMMICK, B.Sc., has been made Manager of the Industrial Motor Sales Department and MR. H. R. CANNING replaces Mr. Dimmick as Manager of the Marine Department. MR. A. G. W. CANNON, A.M.I.P.E., has been appointed Manager of the Birmingham Works in succession to the late MR. E. M. W. BOUGHTON, M.C.

THE Directors of The Anglo Metal Co., Ltd., announce that MR. C. SUSSMANN resigned his position as Joint Managing Director and Member of the Board of the Company, with effect as of October 31st, 1951, and that MR. F. C. CHISNELL is now Managing Director.

MR. T. P. D. SPENS is now Chief Buyer of Stewarts & Lloyds, Ltd., in succession to MR. JOHN CRAIG, who has retired after 40 years' service.

GUEST KEEN BALDWINS Iron & Steel Co., Ltd., Cardiff, announces that MR. H. W. A. WARING, C.M.G., A.C.A., is relinquishing the appointment which he has held for the last four years as Secretary of the Company and its subsidiaries, in order to take up an appointment as Director of the Power and Steel Division of the Secretariat of the United Nations Economic Commission for Europe, in Geneva. MR. L. R. P. PUGH, A.C.A., has been appointed to succeed him.

THE Metropolitan-Vickers Electrical Co., Ltd., announces that on September 1st, 1951, MR. S. A. GHALIB was appointed Assistant Chief Engineer, Electronic Control Department. MR. GHALIB is a member of the Ministry of Supply Technical Committee on servo mechanisms.

MR. JOHN MCKAY, Melting Shop Manager of the Lanarkshire Steel Co., Ltd., has retired after 32 years' service. He remains a Consultant of the Company.

LT.-COL. R. D. GOODHIND, Assistant to the District Goods Superintendent, British Railways, at Sheffield, has been appointed Transport and Traffic Superintendent of Newton Chambers & Co., Ltd. MR. F. NORMAN has been appointed Road Transport Manager.

MR. E. H. DISCOMBE, a Delegate Director and Commercial Manager of Murex Welding Processes, Ltd., Waltham Cross, Herts., has recently retired after over 35 years' service with the Company. MR. DISCOMBE was a founder-member of the Premier Electric Welding Co., Ltd., in 1918, and was its first Secretary and later, Assistant Manager. With the amalgamation of the Company with Murex Welding Processes, Ltd., MR. DISCOMBE took up the position of Commercial Manager and later became a Delegate Director. In this capacity he was responsible for the sales of Murex electrodes and general administration.

MR. C. W. STEWART has been appointed General Manager of Messrs. Charles W. Taylor & Sons, Ltd., Ironfounders and Engineers, South Shields. Mr. Stewart joined the firm in 1947, when he was appointed Works Manager. MR. E. TOWNS has succeeded Mr. Stewart as Works Manager, and MR. S. W. HAYNES, who has been with the Company for about 40 years, has been appointed Secretary.

MR. G. N. MAY has joined the Sales Organization of Platers and Stampers, Ltd. Until recently he was Assistant Manager (Commercial Division) of Richard Thomas & Baldwins, Ltd., and was in charge of some tinplate sales.

MR. T. J. MAKIN will retire from his position at the Brightside Foundry & Engineering Co., Ltd., at the end of this year, after 20 years' service as Secretary of the Company. MR. R. IVOR SLATER, the present Assistant Secretary of the Company, will succeed him.

IN recognition of his 21 years' service as Chairman and Managing Director of James Neill & Co. (Sheffield), Ltd., on October 8th an inscribed silver salver was presented to COL. F. A. NEILL.

AT the end of this year, MR. RICHARD ELSDON will be retiring from his position as Librarian of the Iron and Steel Institute and Institute of Metals Joint Library. Mr. Elsdon joined the staff of the Iron and Steel Institute in 1904, was appointed Library Assistant in 1907 and Librarian in 1908. He has also been Librarian of the Institute of Metals since 1937. MR. A. E. CHATTIN, Assistant Secretary since 1925, is to be Assistant Secretary and Librarian, and MR. ANTHONY POST will be Joint Assistant Secretary, as from January 1st, 1952.

Obituary

We regret to record the following deaths :—

MR. W. B. PARKER, F.R.I.C., who died on October 12th, at the age of 77, had retired from the British Thomson-Houston Co., in 1946, after 44 years' service. Mr. Parker was the company's chief chemist and metallurgist from 1902 until 1943, when he was appointed B.T-H. consultant chemist and metallurgist.

MR. ALBERT E. HANCOCK who was service manager of the Hunslet Engine Co., Ltd. He was well known for his work in connection with his company's flameproof mine locomotives, both in this country and abroad where he had travelled to instal Diesel-mechanical locomotives. Trained at Kerr Stuart's, after a short period with the North British Locomotive Co., Mr. Hancock joined Hunslet over 20 years ago.

DR. ANTON FREDERIK PHILIPS, who died on October 7th, at the age of 77, was President of the Board of Directors of Philips Electrical Industries at Eindhoven, Holland. The great Philips factories in Eindhoven were founded in 1891 when Dr. Philips' brother, Gerard, started a small electric lamp factory. It was not successful until Dr. Anton Philips took charge of the commercial side. For 55 years he devoted all his energy and ability to a concern which was to earn a world-wide reputation.

MR. E. W. WALKER, Director and Secretary of Gibbons (Dudley) Ltd., and Gibbons Bros., Ltd., on October 9th, at the age of 60. He joined the firm of Gibbons Bros., Ltd., in 1907, and subsequently became Chief Accountant, a position which in 1943 he combined with the office of Assistant Secretary. On the retirement of Mr. H. V. Stanton, in April, 1946, MR. WALKER was appointed Secretary of Gibbons (Dudley) Ltd., and Gibbons Bros., Ltd., and in April, 1948, he was elected to the Board of Directors. He continued to hold the combined office of Director and Secretary of the two Companies until his death.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Hydraulic Scrap Metal Baling Presses

In these days of metal shortages when it is essential that every ounce of scrap metal should find its way to the re-melting furnaces, the handling and transport of light scrap presents a problem which can be satisfactorily answered by the use of scrap metal baling presses. Messrs. Fielding & Platt, Ltd., have specialised, for many years, in the design and manufacture of a wide range of hydraulic scrap metal baling presses to meet the needs of the engineering industry, steelworks, scrap metal yards, and other organisations.

These hydraulic baling machines are of the single, double and triple action types, and are mostly produced as self-contained units, complete with hydraulic pumping unit, control station and the necessary pipework. Powers of the presses vary according to specific baling requirements, but it is general to say that the range of " Fielding " Hydraulic Scrap Metal Baling presses will produce bales the weights of which vary from ½ cwt. to 1 ton each.

Included in this range is the " Fielding " Hydraulic Single Compression Scrap Metal Baling Press which is suitable for baling such scrap metal as ferrous, and non-ferrous clippings from sheet metal, also waste oil drums, tins, cans, etc., and general light steel scrap. This latest press incorporates the distinctive features of being fully self-contained with hydraulic pumping unit, control station and piping, and requires the minimum installation and maintenance costs. The machine is very simple to operate without the use of skilled labour, and at the same time it gives a very high bale production rate. The size of the box is 49 × 24 × 24 in., the depth with the cover closed being 16 in. Depending on the loading of the box the size of bale produced is 24 × 16 × 6–8 in., and an output of 30 bales (up to 3 tons) per hour can be achieved.

The machine is fabricated from mild steel plates, suitably tied together so as to give a rigid construction, and the inside of the box is lined with special steel wearing plates. The sides of the box adjacent to the lid are fitted with special serrated shearing members, so as to eliminate any tendency for the lid to jam. The serrated shearing members are fully reversible.

The initial compression on the bale is by means of the cover, actuated by a hydraulic cylinder and ram, the cylinder and ram being contained in a fulcrum type crosshead, and the final or horizontal compression is by means of a horizontal cylinder and ram mounted within the main frame of the press. The ram head is fitted with a special steel wearing plate. The bale is ejected through the end of the machine, this end being formed by a manually operated door, which is swung open for the ejection of the bale. Both the cover and horizontal rams are of the double acting type, and the ram packings, with the exception of the piston rings on the ram heads, are of the outside packed type, suitable for use with oil as the pressure medium and easily repacked.

The hydraulic power for the operation of the machine is provided by a " Fielding " High Speed Variable Delivery Radial Pump employing oil as the pressure medium, which is driven through the medium of a flexible coupling, by a 12·5 H.P. foot mounted, totally enclosed, continuously rated squirrel cage motor at 1,460 r.p.m. from a 400/440 volts, 3 phase, 50 cycles supply. This gives the required delivery output of gallons per minute at the operating pressure of 2 tons per square inch. The pressure control of the pump delivery is so arranged to make the best use of the available H.P. and to keep the time cycle to a minimum.

The press control station is provided with hand lever operated piston type control valves for " Cover " and " Bale," and pressure gauges graduated in pounds per square inch and tons on ram are provided for the " Cover " and " Bale " cylinders.

Fielding & Platt, Ltd., Atlas Works, Gloucester.

Wedco Aircush Lowerator

An ingenious machine has been manufactured by the British Wedge Wire Co., Ltd. It has been designed to operate between gravity roller or power-driven conveyors at different floor levels and it will lower, safely and speedily, such items as cases, crates, barrels, bales, etc.

The machine, known as the Wedco Aircush Lowerator, is fully automatic and requires no power other than gravity. It comprises a cylindrical tube or pillar, which extends from the higher level to the lower one through an aperture in the floor, to which is attached a movable carriage that accommodates the article to be lowered. The carriage is counter-balanced by a piston inside the tube and as the article rolls into position, its weight takes the carriage down towards the lower level. The piston is drawn up inside the tube and the air that it displaces escapes through a series of ports. As the carriage nears the end of its drop the piston passes the last port in the tube and the resulting air compression brings the carriage to an air-cushioned standstill. At the same time it is tipped forward slightly and the article continues on its journey.

The carriage then begins to ascend rapidly as the heavier piston drops down inside the tube and air cushioning again takes place as the carriage reaches its original position. At the same time it trips a selector device which allows the next article to roll into position.

British Wedge Wire Co., Ltd., Academy Street, Warrington.

Simplified Single-Spindle Automatic

A NEW simplified type of single-spindle automatic machine for production of the many components which do not require a multiple-operation machine, and which retains the accuracy and speed of their well-known range, is now being made by B.S.A. Tools Ltd. Two sizes are at present available but if the demand arises the range will be increased. The No. 48 has a bar capacity up to $\frac{1}{2}$ in. diameter, and No. 68 is intended for a bar of $\frac{3}{4}$ in. diameter.

The basic construction of these machines is similar to that of the established B.S.A. single-spindle automatic screw machines, but in many respects the design has been altered to achieve the purpose of this new machine. Provision is made for one tool in addition to those on the cross slides, and the extended feed of bar stock permits the production of parts considerably longer than those usually accommodated on automatics, on the $\frac{3}{4}$ in. capacity machine (No. 68) a feed of 9 in. can be utilised.

Ample allowance is made for chips and their easy removal, and a compartment for storage of change gears is provided. Drive is by self-contained motor mounted at the rear of the base of the machine, V-ropes being used to connect with the main gearbox shaft. All gearbox shafts are carried on ball bearings and are lubricated automatically. A range of ten forward spindle speeds can be obtained on the No. 68 and 12 on the No. 48 by changing one pair of gears.

The plain workspindle is rigidly constructed to withstand maintained high speeds and heavy cuts and is mounted on roller bearings. Collets are toggle operated and can be adjusted to suit stock diameter. The spindle drive is by a single sprocket which connects with a chain in the gearbox, correct chain tension being maintained by an adjustable jockey sprocket in the machine base. Adjustment on the No. 68 is made by the operator, but is automatic on the No. 48 since the smaller machine requires more frequent alteration in chain tension.

The front camshaft controls the cross slides, stock feed, work chute, and collet opening and closing. It is driven by the lead camshaft from the backshaft, through a worm-drive and pick-off gears which provide 15 different cycle times entirely independent of the spindle speeds. Changeover from one cycle time to another is effected simply and rapidly by pick-off gears at the end of the machine.

The backshaft is driven at a constant speed by a belt connected with the main drive shaft and can be engaged or disengaged by using a lever to operate a clutch. A handwheel is provided for manual operation of the machine for the purpose of setting up, etc. Dog clutches to control stock feeding, and collet opening or closing cams are mounted on the backshaft, and are operated by adjustable trips positioned on the front camshaft.

The cross slides are totally enclosed at the front to prevent the entrance of swarf, and operation is by disc type cams mounted on the front camshaft. A third, or vertical slide, can be fitted when required, the motion for this being taken from an additional cam on the front camshaft. Provision is made for the independent setting of each slide either forward or backward in relation to the centre line of the spindle.

In this simplified automatic, the conventional indexing turret is replaced by a plain slide carrying one tool holder which will accommodate any turret tool of standard type. When only two tools are necessary for the component, these will be accommodated on the cross slides, and the tailstock slide can then be used as a simple bar stop, or, alternatively, if the components being produced are very long, a combined revolving steady and stop can be fitted. It is imperative for this tailstock slide to maintain rigidity under heavy cuts, and this is achieved by a strong and robust slide. On the No. 68 size it moves on large square section ways, while the No. 48 machine uses dove-tailed ways, both types incorporating a taper gib to take up wear. Feed is actuated by a cam-operated quadrant and rack. Provision has been made to deal with the production of components of various lengths, by enabling the tool holder to be adjusted forward or backward in relation to the slide, thus simplifying tool setting and considerably reducing the time delay.

All headstock bearings and cross slides receive automatic lubrication from a pressure plunger pump which draws clean oil from the tank mounted at the top of the base casting. Chain and gearbox are lubricated by a gear type pump on the circulating principle drawing oil from the sump. All other bearings are gun-lubricated. Filtered coolant is pumped at a constant pressure through a delivery pipe having a swivelled nozzle which can be securely clamped after positioning.

Separation of swarf and work is effected by a workchute operated from an adjustable dog on the camshaft. Efficient guarding protects the operator from all moving parts and, where necessary, the guards are arranged to swing clear, so that parts such as the cross slides are easily accessible. Should the machine be subjected to undue strain, a slipping clutch in the cycle time gear train comes into operation and instantly stops all moving parts other than the spindle. Instantaneous stopping is similarly achieved when the remaining bar stock is insufficient to complete another component, the actuating device in this instance being incorporated in the bar feed mechanism. This is a feature of considerable importance since it prevents tool damage which may easily result from a short piece of stock being fed into the collet.

B.S.A. Tools Ltd., Mackadown Lane, Marston Green, Birmingham.

CURRENT LITERATURE

Book Notices

CHEMISTRY RESEARCH, 1950

Published by His Majesty's Stationery Office for the Department of Scientific and Industrial Research. Price 3s. 6d., (90 cents U.S.A.).

THIS annual publication includes the report of the Chemical Research Board and an account of the work of the Chemical Research Laboratory, D.S.I.R., during 1950. A number of items dealt with are of metallurgical interest, perhaps the most important being the corrosion studies.

Fundamental research has taken place to correlate the results of oxidation studies on evaporated metal films under rigorous conditions with similar experiments on massive metal surfaces. Satisfactory reports continue to be received about the corrosion inhibitor developed at the Laboratory. This inhibitor consists of sodium benzoate with a smaller percentage of sodium nitrite in glycol antifreeze, but further investigations are necessary in cooling systems where aluminium is used in conjunction with other metals. Excellent results have been obtained with compounds prepared from nitrogenous bases and carbon dioxide as vapour phase inhibitors. Cyclohexylamine " bicarbonate " has so far proved the most effective.

The Pure Metals Committee has continued its work and the stock of metals now comprises antimony, cobalt, iridium, iron, lithium, potassium, silicon, sodium and vanadium in a satisfactory state of purity. Germanium in a very high state of purity has been prepared at the request of the Radio Research Board, tracer techniques being used to study the removal of the last traces of arsenic.

An independent Microbiology Section was set up at the beginning of the year, and it gave particular attention to fundamental studies of sulphide oxidizing bacteria and their uses. They have been used to counter the nuisance caused by the activity of sulphate-reducing bacteria and, in combination with sulphate-reducers, as a means of producing sulphur. The Section also maintains the National Collection of Industrial Bacteria, from which cultures, particularly of the assay organisms, are supplied to industry.

The Radio-Chemical Group published, through H.M.S.O., a " Handbook of Chemical Methods for the determination of Uranium in Minerals and Ores." The methods described are based on the results of several years' work in the laboratory and include the new chromatographic techniques developed there.

Several papers have been published on the separation of metals by methods based on solvent extraction in conjunction with cellulose and other solid absorbents.

BEAMA GUIDE TO BRITISH ELECTRODES

Published in London by the British Electrical and Allied Manufacturers Association (Inc.). Price 2s. net.

THIS booklet has been prepared by the Arc Welding Electrode Section of BEAMA, which comprises manufacturers of arc welding electrodes and supplies of welding equipment, in order to give those interested in the manual application of the electric arc welding process useful information on some general matters relating to this process.

The booklet includes a brief description of the British Classification of Electrodes, which has now been published by the British Standards Institution as B.S.1719 : 1951, together with advice on how to use this classification. In U.S.A. a different method of classifying electrodes has been instituted and notes on this classification, with comparisons of British and American Code numbers, are given in a separate chapter. Lloyd's approval for electrodes and welds has world-wide recognition, especially in connection with the construction and repair of ships and pressure vessels, and a chapter is devoted to details of the test requirements for such approvals. At the end of this book, lists of mild steel electrodes manufactured by members of BEAMA are given, and these show the British and American Code numbers and Admiralty and Lloyd's approval for each type of electrode.

THE INSTRUMENTATION OF OPEN-HEARTH FURNACES

By the Steelmaking Division Open-Hearth Instruments Sub-Committee of the British Iron and Steel Research Association. 151 pp., 70 illustrations. George Allen & Unwin, Ltd., London, November 1951. 30s. net.

NOT so many years ago a pair of blue glasses which had been used for a number of years by a steel melter were, to him, a priceless possession, because the colour of various parts of the furnace, as viewed through the glasses, was his means of estimating temperature. If he had to get a new pair they would most likely have glass of a slightly different tint and his standards would be upset. In consequence it was by no means uncommon to see a melter wearing badly cracked glasses held together by bits of wire.

During the last few years considerable progress has been made in measuring and controlling such things as roof temperature, furnace pressure, air and fuel flow, draught and so on, with the result that the melter is no longer quite so dependent on his judgment. In 1944 was formed the Open-Hearth Instruments Sub-Committee of the Steelmaking Division of the British Iron and Steel Research Association. Composed entirely of practical men from melting shops, the Committee has been largely responsible for the interest and enthusiasm shown in this country for the application of control instruments to steelmaking furnaces. It is under the official authorship of the Committee that this book, the first to deal exclusively with the instrumentation of open-hearth furnaces, makes its appearance.

Written by pioneers in the field it is intended mainly for those concerned with furnace operation, but it will also be useful to those engaged in instrument maintenance. For this reason abstruse terminology is avoided as far as possible and many actual examples of applications are given. The first part discusses basic principles, including those of automatic control. It suggests how they can be applied to individual furnaces to determine the working conditions which will give the fastest and

most economical operation, and how these conditions can be maintained over a prolonged period within closer limits than is possible on uninstrumented furnaces. The second part is devoted to brief descriptions in non-technical language of the proprietary instruments most commonly used in British melting shops.

Without doubt the application of instruments to open-hearth steelmaking, by enabling furnaces to be run nearer to the limit of temperature, has contributed in no small measure to the high outputs which have been achieved. Mr. F. L. Robertson first Chairman of the Committee, said he had "made steel for many years without instruments and for many years with instruments," and in spite of the difficulties encountered, he gave his unqualified advice to all young melters to use measurement and, when possible, automatic regulation. To those intending to follow Mr. Robertson's advice, this book will be of immense value.

Trade Publications

An excellently produced brochure, "Closeloy Rolls," has recently been issued by Sir W. G. Armstrong Whitworth & Co. (Ironfounders), Ltd., Close Works, Gateshead-on-Tyne. The Company was one of the pioneers in the manufacture and development of high-grade heat-treated rolls, and rollmaking history was made by the decision, following the introduction to this country of the four-high mill, to manufacture the first British alloy cast steel back-up roll. Closeloy rolls, whether iron, carbon steel or alloy steel, are cast and the brochure describes, with copious illustrations, the various stages in the production of these rolls, including the rigorous inspection which they must undergo. Details are given of types of roll produced, for hot and cold rolling, together with the purposes for which they are most suitable.

The Industrial Group of Philips Electrical, Ltd., announce the publication of a new brochure on their '48' Arc Welding Electrode. This 28-page booklet contains full technical information on the Philips '48' together with a great number of illustrations, graphs, photographs and tables. The text matter deals with the theoretical as well as the application aspects and includes items such as "The Functions of the Coating of the Type '48'; resistance to hot cracking; welding procedure; mechanical properties; mild steel welding with the type '48'; high speed welding, etc." The 18 tables, dealing with every type of application for which the Philips '48' electrode is suitable, contain invaluable technical data clearly set out and well illustrated by technical drawings explaining graphically the sequence of welding and the preparation of the material before welding. Copies may be obtained from Philips Electrical, Ltd., Industrial Group, Century House, Shaftsbury Avenue, London ,W.C. 2.

We have received from the Northern Aluminium Co., Ltd., Banbury, a copy of an interesting illustrated brochure dealing with the Company's oldest works at Handsworth, Birmingham. A foundry was built there in 1926 and enlarged several times in the ensuing years. In 1937 a forge was added and further rapid extension took place during the war years. After the war, with the return of keen competition, a review was made of the somewhat irregular layout which had inevitably resulted from continual urgent expansion. As a result a scheme of reorganisation was prepared, aiming at reducing internal transport costs, and melting costs, and satisfying the due demands of foundry and forge by re-equipping the toolroom with modern time-saving machinery. A brief account of the scheme of modernisation is included in the brochure, which deals, in the main, with the production of Noral castings and forgings at Handsworth Works. Also included is an essay on design and properties, illustrated by examples of some of the most interesting components the works have produced.

The name of Carl Reichert occupies an honoured place in the optical instrument field, and 1951 sees the centenary of his birth at Sersheim in Württemberg, and the seventy-fifth anniversary of the foundation of his firm. In celebration of this double jubilee Optische Werke C. Reichert has issued an illustrated booklet in which is traced the history of the firm from its foundation to the present day. As might be expected, the quality of the illustrations, which are arranged in three groups, is excellent. The first group show the premises which the firm has occupied at various stages in its transition from handicraft to industry, whilst the second presents glimpses of various stages in manufacture. Finally, a series of photographs of modern products of the Company are set out against a pictorial background illustrating their earlier counterparts.

We have received from The Power-Gas Corporation, Ltd., Stockton-on-Tees, a leaflet dealing with P-A (Pease-Anthony) Gas Scrubbers. These are of two types: the P-A Cyclonic Scrubber which assures virtually complete removal of micron-size dust with a pressure loss of 2–4 in. W.G.; and the P-A Venturi Scrubber which, with a pressure loss of 10–15 in. W.G., assures virtually complete removal of sub-micron dust and mist.

Books Received

"Electrolytic Polishing and Bright Plating of Metals," by S. Wernick, Ph.D., M.Sc. Foreword by Ulick R. Evans, M.A., Sc.D., F.R.S. 2nd Edition. 243 pp. inc. bibliography and indices. London, 1951. Alvin Redman, Ltd. 30/– net.

"Chill-Cast Tin Bronzes," by D. Hanson, M.Sc., D.Sc., and W. T. Pell-Walpole, Ph.D., D.Sc. 368 pp. inc. bibliography and indices. London, 1951. Edward Arnold & Co. 75/– net.

"Industrial High Vacuum," by J. R. Davy, B.Sc., F.P.S. 243 pp. inc. appendices and index. London, 1951. Sir Isaac Pitman & Sons, Ltd. 25/– net.

"The Wire Reference Year Book and Directory." Festival of Britain Edition. Compiled by D. J. Blashill and edited by Neil Lindsay. 164 pp. Salop, 1951. Owen's Library Printing Works, Oswestry. 30/– net.

"The Manufacture of Iron and Steel" Vol. 2, "Steel Production," by G. Reginald Bashforth, F.I.M. 461 pp. inc. index. London, 1951. Chapman & Hall, Ltd. 45/– net.

"Facts From Figures," by M. J. Moroney. 472 pp. inc. bibliography, answers and index. Penguin Books, Harmondsworth, Middlesex. 5/–.

METALLURGICAL DIGEST

Thin, Attractive Metal Coatings Produced by Vacuum Method

WHEN a metallic surface must be developed on a non-metallic material there is a choice of several methods. Among these is the process of vacuum coating, which though not new has recently widened in scope, according to Kenneth Rose,* who claims it to be one of the simplest of procedures. The pieces to be coated are suitably arranged in a container, in which a small wafer or wire of the metal to be applied is attached to a small loop of tungsten wire, and air is exhausted from the container to high vacuum. An electric current is then passed through the tungsten loop, heating it to incandescense and vaporising the metal wafer. The vaporised metal is deposited on the surfaces of the pieces in the container.

The vacuum coating process is not strictly limited to the coating of non-metallics, nor to the applying of metals to the parts to be coated. One of the important uses for the process is in the coating of optical lenses with an anti-reflection film of a chemical compound, usually magnesium fluoride.

Most of the vacuum coating, other than that of optical lenses, consists of the application of a metallic film to a non-metal, and the metal most commonly used is aluminium. Aluminium vaporises easily, is tarnish-resisting when deposited, and is low in cost. Other metals that can be used for vacuum coating include gold, silver, chromium, nickel, zinc and Inconel.

The equipment consists of a container for the work, which can be a bell jar for a small unit, or a metal vacuum chamber for larger installation; vacuum pumps, usually of the diffusion type, to exhaust the air from the container to a vacuum of one-tenth of a micron of mercury; one or more electrodes holding the heaters or filaments used to evaporate the coating metal; and the necessary power supply and control gauges. Special devices, such as heaters for continuous vaporising of metal, and a winding mechanism to permit rolling and unrolling of strips of stock during continuous coating, can also be a part of the machine.

Pieces for vacuum coating need not be cleaned unless obviously soiled, or unless they have been handled. Development of a bright, adherent film of metal requires a vacuum of a high order, however, and pumping equipment must be of a type intended for such use. For the rapid evacuation of air from the vaporising chamber, a roughing pump can be used to remove most of the air, with the oil diffusion pumps to carry the vacuum to the desired limits. To avoid contamination of the film, the vacuum must be taken to a pressure of 1 micron of mercury at most, to 0·5 micron preferably, and to 0·1 micron for the best results.

From *Materials and Methods*, **33**, No. **6**, 71-73.

Rare Earths in Aluminium Baths Give Attractive Hot-Dip Coatings

By Webster Hodge and E. M. Smith

ALUMINIUM-COATED wide steel strip has been successfully produced commercially for some years, but less attention has been given to hot-dip coating of wire and narrow strip, and still less to the coating of miscellaneous steel products. Such materials are amenable to aluminium coating, however, and the general process offers great promise for commercial work. In particular, progress has been made on the use of alloying constituents in the aluminium bath to give an attractive surface to the work and to assist in avoiding the use of a flux.

While many refinements in methods of preparing and handling the steel sections during coating have been developed to overcome the difficulties encountered in hand dipping, it is necessary to change the character of the bath itself if satisfactory work is to be produced.

Small amounts of magnesium and beryllium, magnesium and lithium, or a combination of these, decrease the rate of oxidation and eliminate oxide skins on molten aluminium. Silicon additions to aluminium baths used for hot dipping of steel reduce the amount of brittle iron-aluminium compounds formed at the iron-aluminium interface.

Experimental work has demonstrated that fairly good coating can be obtained in baths of pure aluminium and of aluminium-5% silicon alloy. The addition of magnesium increases the amount of oxide skin on the bath surface. The addition of magnesium and lithium, or of lithium alone, to baths containing magnesium, or magnesium and silicon, does not decrease the amount of oxide sufficiently to permit alloys of this type to be used for hot-dipping baths. Although the best coatings obtained are complete and highly corrosion resistant, they are unsatisfactory in æsthetic appeal. Spots of dross, or discolorations from oxide stains, are found on almost all test panels.

Minute amounts of beryllium added to an aluminium dipping bath effect a measurable improvement. With additions of beryllium as small as 0·004% the oxide skin on the bath maintains its bright metallic lustre for a much longer time after scraping than does the same bath without beryllium. This beryllium content will not decrease the roughness on the coated surface, but it does help in eliminating oxide stains. Increasing the beryllium content to 0·014% causes a further improvement in the surface of the bath, but larger additions of beryllium do not appear to help in a pure aluminium bath. However, an addition of 0·018% beryllium to an aluminium-5% silicon bath immediately benefits the coatings.

The roughness caused by adhering dross, and the tendency for considerable aluminium to be held at the drip edge on hot dipping, points to the need for reducing the surface tension of the metal or dissolving the oxide film. The addition of cerium looks like a logical step. Since cerium is probably the only metal which has higher molecular heat than aluminium, it can be used

From *Materials and Methods*, Sept., 1951, pp. 95–6.

to dissolve the skin of Al_2O_3 which forms on the surface of molten aluminium.

"Mischmetall," an alloy of about 48–52% cerium, approximately 38% lanthanum, balance neodymium, praseodynium, terbium, yttrium, illinium, and samarium, with about 2% iron and 0·1–0·3% silicon, has the same effect in an aluminium alloy as cerium.

"Mischmetall" added to pure aluminium baths, increases and thickens the amount of oxide on the bath. However, the increased thickness of the oxide surface does not increase coating difficulties. Instead, the iron-aluminium compound, which causes lumps to appear on the coated surface without the "Mischmetall" addition, is dispersed and distributed uniformly throughout the coating.

Beryllium in amount up to 0·2% in an aluminium-5% silicon bath improves the appearance of test panels, but the coatings tend to be incomplete. When 1·7% of "Mischmetall" is added, complete and attractive coatings are obtained.

The Role of Boron Steels in the Present Emergency

By T. R. Wray

THE seriousness of the critical alloy problem and the return of controls to bring steel alloy supply and demand into balance are forcing plans for the future. Should war break out, the military appetite for alloy steels may leave little or none for peaceful uses. One ray of hope, at least as far as heat treating steels are concerned, is the potential of the element boron for increasing the hardenability of steel. In most applications of constructional alloy steels, boron can replace a sizeable amount of critical alloying elements. In addition to conserving these elements, however, boron improves the hot and cold working properties of the steel, gives a shorter annealing cycle, and imparts better machinability. When boron is used as an alloy replacement in carburising steels, the treatment is simplified by the shorter annealing cycle, and the retained austenite and undissolved carbides in the carburised case are minimised.

Boron is used in steel to increase the hardenability; that is to increase the depth to which the steel will harden when quenched. Its effect on hardenability is very potent, but this decreases with increasing carbon content, thus boron is most effective in conserving critical alloys in the low carbon steels. The carburising grades of alloy steel, with less than 0·30% of carbon, are more fertile fields for boron substitution than spring steel, at 0·60% carbon.

Isothermal transformation diagrams are helpful in understanding the behaviour of boron steels during conventional quenching, normalising and annealing heat treatments. If the time from the beginning of transformation at the nose of the curve is approximately the same for a given boron steel and a higher alloy steel (i.e., they have equivalent hardenability), the time required to complete the transformation will be much shorter for the boron than for the high alloy. Boron delays the start of transformation but delays the completion only slightly. This has practical significance, since a low alloy boron, used to replace a higher alloy and give the same properties when hardened, can be annealed with a much shorter cycle than the original high alloy steel. The boron steel is also much softer in the as-rolled or normalised state, provided that the piece is large enough to prevent air quenching.

Properties of Boron Steels

Boron tends to lower the austenite coarsening temperature of a steel, this effect, however, can be counteracted by a judicious increase in the aluminium addition used for grain size control. The exact effect of boron on notch toughness is not clear. Comparison of a given composition with and without boron indicates that the addition increases notch toughness at high hardness levels—R.50 and above—and reduces it at lower hardness. When a low alloy boron composition is compared with a higher alloy steel, the effect of the boron on the notch toughness may be masked by the other elements. However, the notch toughness in all cases is adequate for most engineering applications. The endurance limit and the endurance ratio of a boron steel are the same for a given hardness as values shown by other alloy steels heat treated to the same hardness.

In the amount normally used, boron does not increase the resistance to softening on tempering, as other alloying elements do, particularly vanadium, molybdenum and tungsten. When boron is used to replace these elements partially or completely to obtain equivalent hardenability, it is generally necessary to use a lower temperature to get a given hardness and strength. Although it is possible to obtain an equivalent hardness with a boron steel, it is advantageous to make experimental tests to determine the correct tempering temperature.

Since boron apparently does not retard softening appreciably during the tempering, these steels will not be adequate replacements for the higher alloy steels containing molybdenum, vanadium and tungsten that are designed for high temperature service.

When the steel is annealed to a micro-structure of pearlite, or of ferrite and pearlite, such as might be encountered in the centre of large pieces of moderate or low hardenability grades, boron lowers the tensile strength and the notch toughness. For this reason the hardenability of a boron steel must be sufficient to obtain martensite prior to tempering, so that the optimum properties can be developed at the point where the highest stresses are encountered.

Because of the necessity of conserving nickel, chromium and molybdenum, the American Iron and Steel Institute has announced two new series of steels, designed to accomplish this purpose. These steels, 80Bxx and 81Bxx, are low nickel, chromium, molybdenum compositions in which boron has replaced about half the critical alloy content of the 8600–8700 steels, which were the basic National Emergency steels of the last world war and have since taken their place in the mass production industries. These new alloys should be able to replace 70 to 80% of the present constructional alloy steels on an equivalent hardenability basis. The composition of these steels may have to be altered slightly, based on production experience, since only a few production heats have been made. So far, the hardenability of the production heats seem to be exceeding the limits predicted from laboratory data.

From *Materials and Methods*, **24**, No. 2, 57–60.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

NOVEMBER, 1951 Vol. XLIV, No. 265

The Spectrographic Determination of Alumina in Silica Brick

By W. S. Sykes and D. Manterfield, F.I.M.

Steel, Peech & Tozer Branch of The United Steel Companies, Ltd.

A simple method of determining the alumina content of silica bricks by spectrographic means is described, having an accuracy of the order of ± 0·05% alumina. The method may also have possibilities for use in spectrographic analysis of other oxide bearing materials such as slags.

SINCE the determination of alumina in silica brick by chemical means is a slow process, work was put in hand to develop a process for this determination by a spectrographic method.

Several spectrographic techniques for the analysis of oxide-type materials have been published in the literature.[1, 2, 3, 5, 6] The majority of these methods use a sample of powdered brick together with some form of buffer, graphite or CuO, in order to promote satisfactory excitation and in some cases to provide an internal standard. These samples are either placed in a specially prepared cavity of a graphite electrode or pressed into a briquette which serves as the sample electrode.

Most of these methods use some form of controlled spark excitation with either an air-interrupted spark[7] or a rotary interrupter[8] in the circuit. With the apparatus at our disposal it was not possible fully to reproduce these conditions and experimental work using an uncontrolled spark failed to give satisfactory reproducibility of the necessary lines. It was, therefore, decided to experiment with intermittent A.C. arc excitation[4, 11] and it was found that this source gave better reproducibility and consistent results.

The procedure adopted for forming the sample electrodes is that described by Irish[1] and consists of dipping the end of a graphite electrode into a molten fusion mixture of the brick sample and alkali salts. The resultant tip on the electrode is robust enough to withstand excitation by an A.C. arc source. This method of electrode preparation has not only given the best accuracy but it has the advantage that it can be prepared quickly.

Procedure

In general, this method involves fusing a sample of powdered brick with a fusion mixture consisting of sodium carbonate, borax and niobium pentoxide, the last being used as an internal standard. A short graphite electrode dipped into the molten fusion will have an adhering tip which contains the brick and internal standard in solid solution.

The Fusion Mix. This mixture contains 49·25% sodium carbonate, 49·25% borax and 1·5% niobium pentoxide. Each of these compounds is passed through a 120-mesh sieve before weighing. The prescribed amounts are then mixed for a minimum period of 24 hours. The mixing is done in a bottle which is clamped to a metal frame at an angle of 45° and rotated by an electric motor through a simple reduction gear to give a rate of 45 r.p.m. (Fig. 1). In practice 150 grm. of the fusion mix is made at a time.

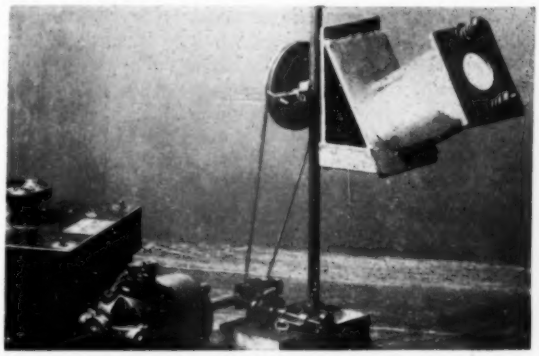


Fig. 1.—Mixing device for powders.

Preparation of Sample and Electrodes. A sample is prepared for analysis by placing 1·90 grm. of the fusion mix in a 25 ml. platinum crucible. 0·10 grm. of the powdered brick sample (80 mesh) is placed on top of the fusion mix and the two stirred slightly together. The 2 grm. of sample in the crucible contains 0·93575 grm. of sodium carbonate, 0·93575 grm. of borax, 0·0285 grm. of niobium pentoxide and 0·10 grm. of the brick sample. This is fused as described later.

The electrodes are cut from H.S. Graphite rod, 6·5 mm. dia., to a length of approximately 1 in. with flat ends. It is essential to remove the graphite dust, caused by the cutting operation, from the ends of the electrodes.

Fusing the Sample. The platinum crucible containing the sample and fusion mix is placed in a small electric furnace which is held at a temperature of 1,100°–1,150°C. (Fig. 2). A cover is placed over the furnace opening and the mixture is allowed to fuse for 4 minutes. At the end

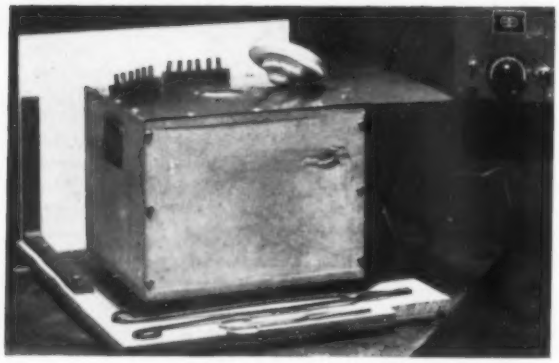


Fig. 2.—Electric furnace for fusion of the sample.

of this time the furnace cover is removed and an electrode, which has been preheated to about 800° C., is dipped into the molten fusion. The preheating of the electrode is accomplished by holding the electrode, in a pair of 15 in. long tongs, above the crucible for a few seconds. If this precaution is taken, the fused material will adhere tightly to the electrode forming a solid tip of even thickness. As many as six electrodes may be tipped from a single fusion. If the electrodes are to be used immediately they should be allowed to cool slowly by placing them in a sample tray which rests on top of the furnace. Tipped electrodes which are not to be used for immedate exposures should be stored in a drying oven, at a temperature of 105° C., as the fusion tip is hygroscopic.

Excitation of Samples. For each exposure one tipped electrode is used with a counter electrode of graphite. The counter electrode has the same dimensions as the sample electrode. The electrodes are set vertically, in special holders (Fig. 3), with the sample as the lower electrode. The analysis gap is set at 2 mm. by using a feeler gauge between the tipped surface of the sample electrode and the graphite surface of the counter electrode. An intermittent A.C. arc is used for excitation.

Exposure Conditions. A Hilger Large Quartz Spectrograph is employed, details of the settings and auxiliary equipment being as follows:

Source to slit distance .. .. .. 39 cm.
Wavelength setting .. .. .. 2,700 Å–4,400 Å
Slit width .. .. 0·015 mm.
Slit length .. .. 2·5 mm.

Current—Adjusted to 4 amp., reading on Ammeter *A2* (Fig. 4), with the analysis gap short circuited. Two graphite electrodes, with flat ends, are placed in the electrode holders to make this adjustment.

Electrodes—*Upper:* Graphite rod, approx. 1 in. long, 6·5 mm. dia., with flat end.
Lower: Graphite rod, approx. 1 in. long, 6·5 mm. dia., with flat end tipped with the fusion.

Analysis Gap—2 mm. (set by feeler gauge).

Plate—Ilford Thin Film Half Tone.

Exposure—60 seconds (no pre-arc)—Triplicate exposures are made for each sample, thus requiring that a minimum of three electrodes be made from each fusion. One counter electrode can be used for the three exposures on the same sample.

Processing—The plate is developed in M.Q. developer for 2 minutes at 67° F. (Formula given in Appendix). Fixing and washing is routine and described in Appendix I.

Plate Calibration. The relative intensity method of plate calibration is used.[9, 10] From each new batch of plates, three are selected at random and two pure iron spectra are exposed on each plate according to the following details:—

Electrodes—*Upper:* Pure graphite with 80° cone.
Lower: Pure iron electrode, 7 mm. dia., with 45° blunted cone.

Analysis Gap—Adjusted to 4 mm.

Current—5 amp. D.C.

Exposure—10 seconds.

Processing—As in normal working.

The characteristic curve is determined by reading a group of homologous iron lines whose relative intensities have been previously established. The microphotometer is adjusted to give a full scale deflection of 50 divisions through the clear portion of the plate near to the group of lines. The density of each of the iron lines is measured for each of the iron arc spectra and the results obtained for each line are averaged. These average density values are then plotted against the log of the relative intensity values (Appendix I).

Line Pair. The line pair used for the analysis is the aluminium line 3082·155 Å and the niobium line 3152·159 Å.

Analytical Curve. Six samples of silica bricks with alumina contents giving a range of 0·20–1·70% were selected as standards (Table I). Three exposures were made on each standard and the densities of the aluminium and niobium lines read on the microphotometer for all the spectra. These density readings were then converted to relative line intensities by reference to the plate calibration curve. From these values the log intensity ratios, INb/IAl, were obtained. To construct the standard curve, the log-intensity ratio was plotted against the percentage of alumina (Fig. 5).

It is necesary to construct a fresh working curve each time a new fusion mixture is put into use. The index value of the working curve can be adjusted to a higher concentration of alumina, if desired, by the addition of more niobium pentoxide to the fusion mix.

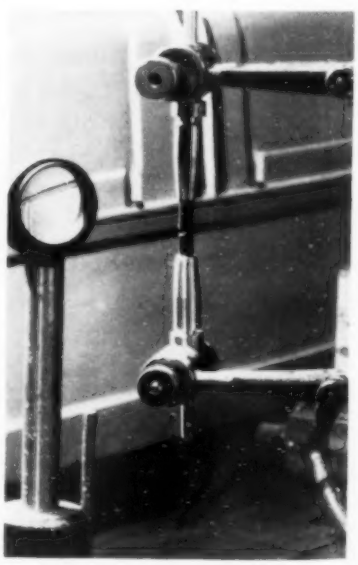
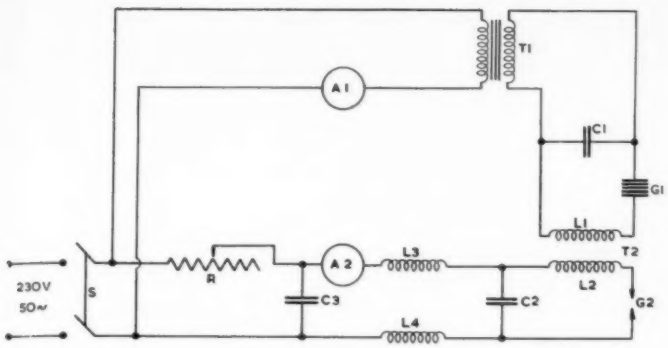


Fig. 3.—Electrodes in special holders. The lower electrode is tipped with the sample.



T1 High Voltage Transformer (5,000 volts minimum).
T2 High Frequency Transformer (Tesla Coil). Primary L1, six turns of 14 S.W.G. bare copper wire having a diameter of 12 in. with turns $\frac{3}{16}$ in. apart. Secondary L2, 100 turns of 20 S.W.G. D.C.C. copper wire having a diameter of 9 in. with the turns wound touching.
G1 Auxiliary Spark Gap. (Admiralty Quenched Spark.)
G2 Analysis Spark Gap.
C1 High Voltage Condenser. Capacitance 0·005μF.
C2 High Voltage Condenser. Capacitance 0·005μF.
C3 2,000 volt D.C. test condenser. Total capacitance 48μF. (Six 8μF condensers in parallel.)
L3, L4 Inductances (H.F. chokes) each of 40 turns of 18 S.W.G. enamelled copper wire with the turns wound touching Diameter 2½ in.
R Variable resistance, 50–100 ohm, 5 amp. rating.
A1, A2 A.C. ammeters.
S Double pole switch for controlling exposures.

Fig. 4.—Intermittent A.C. arc circuit.

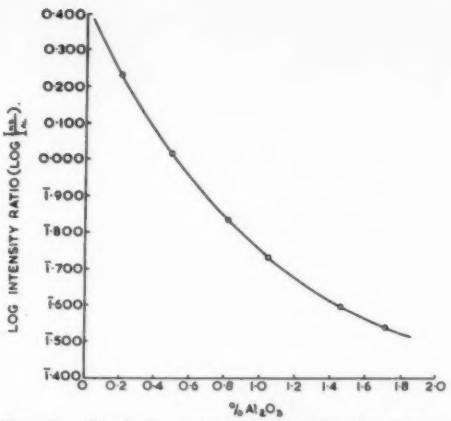


Fig. 5.—Typical working curve for the determination of alumina in silica brick.

TABLE I.—STANDARDS

Sample	Al_2O_3%
1	0·20
2	0·50
3	0·81
4	1·04
5	1·45
6	1·71

Discussion of Results

A series of 22 samples of silica brick kindly supplied by Mr. Lynam of the Oughtibridge Silica Firebrick Co., was put through using the technique already described and the analytical curve shown in Fig. 5. The results are shown in Table II with the chemical figures.

This was considered satisfactory as 16 of these samples were within 0·03% of the chemical figure, the remaining four being 0·06, 0·07, 0·06 and 0·08% difference.

A further series of unknown samples selected by Mason and Speight from the series in their paper[6] and issued under different numbers was analysed and results are given in Table III. No. 4 of this series gave a high figure 1·47% alumina on first excitation, but a further check gave a figure of 1·32% in line with chemical figure of 1·29. The silica pebble sample B gave figures of 1·16/1·15% alumina against a chemical figure of 1·27%. With these two exceptions the results are again quite good.

A third series of quartzite samples which had already been tested by Mason and Speight was issued as "unknown" and the figures in Table IV show these to be of a similar order of accuracy. No. 17 gave two figures of 1·45% and 1·24%, respectively, on two checks against a chemical figure of 1·38%.

These results were considered of sufficient accuracy to adopt the method for routine samples. A selected number of these were checked chemically and the results of these are shown in Table V. It is considered that the accuracy of the method is of the order of ± 0·05% alumina.

Provided the fusion furnace is ready at the required temperature a single determination can be carried out in 35 minutes and a batch of eight samples in 2 hours.

It has the virtue of simplicity in preparation of electrodes as there is no drilling or pointing involved.

The use of an internal standard has the advantage that it is applicable to other bricks, etc., of varying silica content.

The method may also have possibilities for use in spectrographic analysis of other oxide bearing materials

TABLE II.—SAMPLES SUPPLIED BY MR. T. R. LYNAM, OUGHTIBRIDGE SILICA FIREBRICK CO.

Sample	Al_2O_3% Chemical	Al_2O_3% Spectrograph	Sample	Al_2O_3% Chemical	Al_2O_3% Spectrograph
1	0·50	0·47	A	0·84	0·84
2	0·70	0·70	B	0·87	0·84
3	0·81	0·81	C	0·96	0·98
4	0·83	0·86	D	0·97	0·95
6	1·04	1·04	F	0·99	0·92
7	1·18	1·18	G	1·04	1·02
8	1·22	1·20	H	1·08	1·02
9	1·38	1·32	K	1·10	1·08
10	1·40	1·40	L	1·45	1·46
11	1·44	1·47	M	0·36	0·44
12	1·71	1·71			0·44
13	1·73	1·76			

TABLE III.—SILICA BRICKS AND SILICA PEBBLES SAMPLES SUPPLIED BY THE RESEARCH AND DEVELOPMENT DEPARTMENT OF THE UNITED STEEL COMPANIES, LTD.

Sample	Al_2O_3% R.D.D.* Chemical	Al_2O_3% R.D.D. Spectrograph	Al_2O_3% S.P.T.† Spectrograph	Sample	Al_2O_3% R.D.D. Chemical	Al_2O_3% R.D.D. Spectrograph	Al_2O_3% S.P.T. Spectrograph
2	0·85	0·78/0·85	0·90	13	0·95	0·90/0·96	0·98
4	1·29	1·23	1·47/1·32	16	0·90	0·89/0·91	0·97
6	0·81	0·87/0·80	0·90/0·84	20	1·12	1·11/1·13	1·11
7	0·90	0·91	0·90	22	0·81	0·80/0·83	0·75/0·76
8	0·74	0·73	0·81/0·76	24	0·29	0·30	0·29
9	1·00	1·04/1·04	1·04	Pebbles			
10	1·03	0·99/1·10	1·00	A	1·98	—	1·96
12	0·90	1·06/1·09	0·98	B	1·27	—	1·16/1·15
				C	0·99	—	0·97

* Research and Development Department of the United Steel Companies, Ltd.
† Steel, Peech & Tozer Laboratory.

TABLE IV.—SAMPLES OF QUARTZITE SUPPLIED BY THE RESEARCH AND DEVELOPMENT DEPARTMENT OF THE UNITED STEEL COMPANIES, LTD.

Sample	Al_2O_3% R.D.D. Chemical	Al_2O_3% R.D.D. Spectrograph	Al_2O_3% S.P.T. Spectrograph	Sample	Al_2O_3% R.D.D. Chemical	Al_2O_3% R.D.D. Spectrograph	Al_2O_3% S.P.T. Spectrograph
1	0·45	0·47	0·43/0·44	12	0·26	0·26	0·32/0·30
3	0·38	0·39	0·42/0·43	15	0·36	0·36	0·42/0·42
4	0·19	0·20	0·22/0·22	17	1·38	1·34	1·45/1·24
5	0·69	0·73	0·72/0·70	20	0·77	0·84	0·83/0·87
10	0·57	0·63	0·59/0·66				

TABLE V.—ROUTINE SAMPLES

Sample	Al_2O_3% Chemical	Al_2O_3% Spectrograph	Sample	Al_2O_3% Chemical	Al_2O_3% Spectrograph
1	0·30	0·32	6	0·95	1·00
2	1·09	1·07	7	1·03	1·04
3	0·43	0·46	8	1·03	1·04
4	1·09	1·14	9	1·18	1·22
5	0·97	1·00	10	0·30	0·34

such as slags, where the internal standard could be used as a measure of other constituents.

Appendix I—Plate Calibration

Wavelength Iron Line. Å		*Relative Intensity*
3162·229	....	0·11
3163·874	....	0·19
3168·857	....	0·31
3165·006	....	0·42
3165·861	....	0·67
3166·438	....	1·00
3175·447	....	2·00
3180·226	....	3·63
3196·930	....	6·30

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2 Rosza, J. T. Improvement of Analytical Control for Silica Brick. *J.O.A.C.S.*, 1948, **31**, 10, 28.–283.
3 Jaycox, E. K. Spectrochemical Analysis of Ceramics and Other Non-Metallic Materials. *J.O.S.A.*, March, 1947, 162–165.
4 Pfeilsticker, K. *Z. Electrochem.*, 1937, **43** (8), 719–721.
5 Harbison-Walker—Private Communication.

Appendix II—Plate Processing

Developing Solution :—

Metol	1·0 g m.
Hydroquinone	2·2 g m.
Sodium Sulphide (anhydrous)	13·0 g m.
Sodium Carbonate (anhydrous)	9·0 g m.
Potassium Bromide	0·3 g m.
Distilled Water to	1,000 ml.

100 ml. used for each plate :—

Developing Temperature	67° F.
Developing Time	2 mins.

Stop Bath—After developing, rinse the plate in a 2% acetic acid solution.

Fixing Solution—"Amfix"-Ultra-Rapid Fixer (May & Baker, Ltd. product). Fixing time approximately 1 minute.

Washing—5 minutes in running water after which a rinse with distilled water.

Drying—In a current of warm air.

6 Mason, G. L. and Speight, G. E. Spectrographic Determination of Alumina in Silica Brick. Private Communication. *Transactions of the British Ceramic Society, L*, Jan., 1951.
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9 Vaneslow, A. P. and Leibig, G. F. *J. Opt. Soc. Am.*, **34**, 219–221.
10 Hurst, J. E. and Riley, R. V. *Journal of the Iron and Steel Institute*, No. 11, 1946, 133–146.
11 "Polarographic and Spectrographic Analysis of High Purity Zinc and Zinc Alloys for Die Casting." H.M. Stationery Office, 1945. pp. 51, 52.

Transverse Testing Tip

On breaking transverse test bars on most types of testing machines one frequently finds that considerable damage is done to the paint-work and body of the machine by the flying sections of the test bar when it breaks. Injury may also be done to the feet of the operator by the falling bar, or damage to the floor or floor covering in the vicinity of the machine.

With the object of overcoming these disadvantages, the cuffs illustrated in the accompanying photograph were devised and tested in conjunction with a 21 in. × 1·2 in. diameter test bar on a Denison 50-ton Universal Testing Machine. The cuffs consist of two manganese bronze rings, each $1\frac{3}{8}$ in. internal diameter by 1 in. broad and $\frac{3}{16}$ in. thick and linked by a connecting chain strong enough to withstand the strain applied when the test bar breaks. The chain is 9 in. long and is fastened to the rings by means of two $\frac{1}{4}$ in. steel thumbscrews which also act as securing screws on the test bar.

In setting up the bar for test, the cuffs are slipped over one end of the bar and securely fastened in a central position by means of the thumbscrews. When in position the chain should be slightly loose in order that no support is given to the bar under test.

Experience with this device has shown that the broken parts of the test bar, instead of shooting out of the machine, are held together and fall in a central position between the knife edges.

A piece of hard board of suitable dimension should be placed below to receive the broken sections.

[*] Reprinted from *Foundry Practice* by permission of Foundry Services, Ltd., to whom acknowledgment is made.

New British Standard

Method for the Determination of Tin in Ferro-Tungsten and Tungsten Metal. (B.S.1121, Pt. 22 : 1951)

The method is based on the isolation of tin as the sulphide using molybdenum sulphide as a carrier. Tungsten is retained in solution as a complex with ammonium citrate. The tin is reduced to the bivalent condition with metallic aluminium in the presence of an antimony salt and the reduced tin titrated with standard iodate solution. Copies of this standard can be obtained from the British Standards Institution, Sales Department, 24, Victoria Street, London, S.W.1., Price 1s.

The Determination of Iron, Nickel and Manganese* in Copper Base Alloys

G. W. C. Milner† and H. Groom‡

Absorptiometric methods are described for the individual determination of iron, nickel and manganese in most types of copper base alloys. A composite scheme is also described for the determination of these elements from a single sample weight which is advantageous for alloys requiring the determination of all three elements.

FOR some time the absorptiometric methods employed in the Bragg Laboratory for the determination of iron, nickel and manganese in a wide variety of copper base alloys have not proved entirely satisfactory, so investigations have been conducted during recent months to develop quicker and yet more accurate methods. As a result of this work, methods are now available for the determination of each element individually and a composite scheme is also recommended for the determination of the three elements by taking suitable aliquots from a master alloy solution. The composite scheme is designed to use the same reagents and calibration graphs as those prepared for the individual determination of each element, and for convenience the mercury vapour lamp of the Spekker Absorptiometer is used with the H503 heat filters and Ilford green 604 light filters for all determinations.

The Determination of Iron

Vaughan's[1] direct method for this determination using the colour formed by ferric ions with potassium thiocyanate has proved unsatisfactory because of the interfering complex formed by copper ions with this reagent. Edwards and Gailer[2] realised the necessity of removing the copper from solution, but their recommended procedure of precipitating it as copper oxalate before forming the iron thiocyanate colour has proved too time-consuming for inspection analysis. Sherman[3] recently recommended the use of thioglycollic acid for this determination. This reagent forms a suitable colour with iron and simultaneously reduces the copper to eliminate the colour of cupric ions, but unfortunately the intensity of the iron colour fades fairly rapidly under the recommended conditions. Although the iron colour is restored to its original intensity by vigorous shaking, this method did not completely satisfy our requirements. However, the intensity of the complex formed by iron with this reagent is fairly stable in the absence of copper and, moreover, it appears to be less readily affected by slight changes of temperature, reagent concentrations, etc., than the iron-thiocyanate complex. Thioglycollic acid appears therefore, to be a more satisfactory reagent for this determination after the removal of copper. In this country, in the past, the use of thioglycollic acid in analytical chemistry has been very limited because of the penetrating and unpleasant odour of the supplies available. Recently, however, a redistilled quality, which is almost odourless and is known commercially as thiovanic acid, has become available. This has been successfully used by us in this particular investigation.

Goldberg[4] introduced a rapid procedure for removing copper from solution in the analysis of copper base alloys by suspending a strip of aluminium foil with its lower end immersed in the boiling solution of the alloy. Most of the metallic copper adhered to the surface of the aluminium strip whilst small amounts not adhering were readily removed by filtration. This technique appeared to be very suitable and convenient for inspection analysis. Difficulty was encountered, however, in obtaining iron-free pure aluminium foil, although no trouble occurred with supplies of high purity aluminium wire. Using the wire, the most convenient way of introducing the aluminium for deposition purposes proved to be in the form of a small coil prepared from a 3-inch length of 18 S.W.G. wire. Deposited copper adhered fairly firmly but was easily removed by washing with water before re-using the coil for further determinations. With brass samples, zinc remains in solution along with iron and aluminium after the above treatment and under certain conditions causes complications by suppressing the intensity of the iron-thioglycollic acid colour[5]. However, in developing this procedure a sufficient excess of thioglycollic acid has been chosen to minimise this adverse effect of the zinc. Possible interference of aluminium has been prevented by the addition of citric acid before the formation of the iron colour.

The Method in Detail

Range

O—approximately 1·2% using a 4 cm. cell with a 60 ml. dilution.

O—approximately 2·2% using a 4 cm. cell with a 110 ml. dilution.

O—approximately 4·5% using a 2 cm. cell with a 110 ml. dilution.

Solutions Required

Hydrochloric Acid (*sp. gr.* 1·16).

Hydrogen Peroxide (100 *volume*).

Citric Acid (50%)—dissolve 50 g. of citric acid crystals in water and dilute to 100 ml.

Thiovanic Reagent—dilute 25 ml. of thiovanic acid* (strength 76%) to 100 ml. with water. Add 100 ml. of ammonia (sp. gr. 0·88), then dilute to 500 ml. with water and mix thoroughly.

Procedure

Attack 0·5 g. of sample in a 450 ml. conical beaker

* Manuscript received March 9th, 1951.

† Atomic Energy Research Establishment, Harwell, formerly at the Bragg Laboratory, Sheffield.

‡ Bragg Laboratory, Sheffield.

1 Vaughan, E. J., Royal Institute of Chemistry Lectures, 1941 and 1942.

2 Edwards, F. H. and Gailer, J. W., *Analyst*, **70**, 365–8 (1945).

3 Sherman, M., *American Foundryman*, December (1948), p. 55–56.

* Supplied by Evans Chemicals, Ltd., Boreham Wood, Herts.

4 Goldberg, C., *Foundry*, **78**, 170 (1950).

5 "B.D.H. Book of Organic Reagents for Analytical Use," 9th Edition.

TABLE I.—RESULTS FOR IRON IN DIFFERENT TYPES OF ALLOY

Percentage Composition

Type	Cu	Al	Mn	Ni	Zn	Pb	Sn	Sb	Bi	As	Fe Chemical	Fe By alternative Procedure
Aluminium Bronzes												
A1	81·94	9·50	2·36	3·08	0·02	<0·02	<0·02	<0·02	<0·002	<0·02	3·45	3·3
A2	81·4	9·0	3·05	3·16	0·02	<0·02	<0·02	<0·02	<0·002	<0·02	3·53	3·5
A3	81·54	8·91	0·14	4·80	0·10	0·05	0·10	<0·02	<0·002	<0·02	4·60	4·65
Brasses												
Leaded B1	58·32	—	<0·01	0·12	38·06	2·94	0·3	—	—	—	0·14	0·15
70/30 B2	Rest	0·02	0·013	0·16	30·0	0·22	0·11	0·04	0·06	0·07	0·08	0·07
Highly Alloyed B3	55·45	0·18	0·16	2·81	Rest	0·02	1·34	—	—	0·21	0·94	0·95
Propellor Metal B4	55·94	0·30	0·25	0·02	Rest	<0·02	1·30	—	—	—	1·08	1·07
Aluminium Brass B5	76·96	1·85	0·035	0·05	21·04	0·032	0·06	<0·02	<0·002	0·035	0·065	0·065
B.C.S. "B" B6	58·8	1·62	1·03	1·01	33·9	0·78	1·75	0·05	—	0·03	0·87*	0·84
Tin Bronzes												
Gun Metal G1	Rest	—	—	0·77	5·23	2·16	7·5	—	—	—	0·37	0·37
Phosphor Bronze G2	Rest	—	—	—	2·15	0·21	10·0	—	—	—	0·33	0·35
B.C.S. "C" G3	86·84	—	—	0·09	2·53	0·41	9·80	0·04	—	0.05	0·06	0·05

* This figure differs from the reported figure and was obtained by applying the A.S.T.M. method for the determination of iron in brasses.

with 10 ml. hydrochloric acid (sp. gr. 1·16) and 25 ml. hydrogen peroxide (100 volume), keeping the beaker cooled if the reaction becomes too vigorous. When solvent action ceases, boil gently for 2 to 3 minutes. Cool, and dilute to 250 ml. using a graduated flask

Pipette a 10 ml. aliquot into a 50 ml. tall-form beaker and add a coil of high purity aluminium metal prepared by winding a 3-inch length of 18 S.W.G. 99·99% pure aluminium wire around a $\frac{3}{8}$ inch former to give approximately three turns. Bring the solution to the boil and simmer gently for approximately two minutes. Filter through a 9 cm. Whatman No. 42 paper into a 250 ml. conical beaker, washing with small quantities of cold water. Cool, add 1 ml. of citric acid (50%) and proceed according to the iron content :—

(*a*) For iron contents less than 1·2%—dilute to 50 ml. using a graduated flask, add 10 ml. of thiovanic reagent and mix thoroughly.

(*b*) For iron contents from 1·2% to 4·5%—dilute to 100 ml. using a graduated flask, add 10 ml. of thiovanic reagent and mix thoroughly.

Measure the extinction of the solution using an instrument setting of 1·0 with Ilford 604 filters and a 2 cm. or 4 cm. cell. Prepare a reagent blank solution by diluting 1 ml. of citric acid (50%) to 50 ml. or 100 ml. as appropriate, then adding 10 ml. of thiovanic reagent and mixing thoroughly. Measure the extinction of the blank using the above instrument conditions and the same cells. Deduct the blank extinction from the value for the sample solution and obtain the percentage of iron by reference to the appropriate calibration graph.

Calibration

(1) *Solutions Required.*

Standard Iron Solution A.—Attack 1·0 g. of spectrographically pure iron with 20 ml. of hydrochloric acid (sp. gr. 1·16) and 25 ml. of hydrogen peroxide (100 volume) in a 500 ml. conical beaker. Cool if the reaction becomes too vigorous, then warm gently to complete the solution and finally boil for 2 to 3 minutes. Cool and dilute to 1 litre using a graduated flask. 1 ml. is equivalent to 0·20% iron on a sample weight of 0·5 g.

Standard Iron Solution B.—Accurately transfer 50 ml. of solution A to a 250 ml. graduated flask, dilute to the mark with water and mix thoroughly. 1 ml. is equivalent to 0·04% iron on a 0·5 g. sample weight.

(2) *Procedure.*

Add 0·5 g. portions of pure copper to each of eleven 450 ml. conical beakers. Then add the following suitable quantities of the standard iron solutions to cover the range 0—4·5% :—

ml. of Soln. B	Equiv. iron %	ml. of Soln. A	Equiv. iron %
0	0	0	0
2·5	0·10	7·5	1·50
5·0	0·20	10·0	2·00
10·0	0·40	15·0	3·00
20·0	0·80	20·0	4·00
25·0	1·00	22·5	4·50

To each add 10 ml. of hydrochloric acid (sp. gr. 1·16) and 25 ml. of hydrogen peroxide (100 volume). Dissolve the samples and complete exactly as under the heading Procedure. Subtract the extinction value for the sample containing zero per cent. of iron from all other extinction values and plot the difference readings graphically against the iron percentage.

Results

Typical results obtained on applying this method to the determination of iron in different types of copper base alloys are given in Table I.

The Determination of Nickel

Although Haywood and Wood[6] suggest a direct absorptiometric method for the determination of nickel in copper base alloys, for greatest accuracy they recommend a procedure in which the nickel-dimethylglyoxime complex is formed after the electrolytic removal of the copper from solution. Seaman[7] confirms these findings since he recommends the determination of nickel absorptiometrically after dissolving the alloy in nitric acid, filtering off the metastannic acid and electroplating out the copper and lead. This type of procedure is very satisfactory when a fairly complete analysis of an alloy is required, but when only the nickel percentage is needed it becomes time-consuming, due mainly to the electrolysis process. Under such circumstances quicker methods of removing copper are necessary. In a method by Haim and Tarrant[8] the copper is removed by precipitation with ammonium hypophosphite, whilst Goldberg[4] prefers to remove it by deposition on pure aluminium foil. This latter technique appeared very convenient for our purposes, but when difficulty was

6 Haywood, F. W. and Wood, A. A. R., "Metallurgical Analysis by means of the Photoelectric Absorptiometer," London, 1944, p. 87.
7 Seaman, H., *Ind. Eng. Chem., Anal. Edn.*, **16**, 354 (1944).
8 Haim, G. and Tarrant, B., *Ibid.*, **18**, 51 (1946).

experienced in obtaining suitable supplies of aluminium foil investigations were carried out on a procedure utilising the precipitation of copper as cuprous iodide from a suitable small sample aliquot. These investigations eventually resulted in the development of a procedure which has proved very convenient in inspection analysis.

The direct treatment of an acid solution of an alloy with a potassium iodide solution does not precipitate the copper completely, and the traces of copper remaining in solution interfere with the subsequent nickel determination due to the formation of a stable coloured complex with dimethylglyoxime. This interference can be overcome if, after the measurement of the extinction of the final coloured solution, it is possible to selectively destroy the nickel-dimethylglyoxime complex without interfering with the copper complex. The true extinction of the nickel complex can then be readily determined by measuring and subtracting the extinction of the copper complex from the value for the final coloured solution. Investigations were carried out to discover reagents suitable for selectively destroying the nickel dimethylglyoxime complex. Hydrogen peroxide eventually proved to be easily the most efficient reagent for this purpose, although it only appeared to behave satisfactorily in solutions containing traces of copper. The final procedure incorporates the above features and also a blank determination to allow for any nickel present in the reagents and for the colour imparted to the solutions by the addition of the iodine reagent. Also, for convenience, the reagents used for forming the dimethylglyoxime complexes are those recommended by Vaughan[1] in a procedure for the determination of nickel in steel.

The Method in Detail

Range

0 to approximately 0·6% nickel using a 4 cm. cell.
0 to approximately 1·2% nickel using a 2 cm. cell.
0 to approximately 2·5% nickel using a 1 cm. cell.
0 to approximately 5·0% nickel using a 0·5 cm. cell.

Solutions Required

Hydrochloric Acid (*sp. gr.* 1·16).

Hydrogen Peroxide (100 *volume*).

Nitric Acid (*sp. gr.* 1·42).

Potassium Iodide (5%).—Dissolve 5 g. of potassium iodide in approximately 80 ml. of water and dilute to 100 ml.

Sulphuric Acid (1 : 1).—To 200 ml. of water, cautiously add 250 ml. of sulphuric acid (sp. gr. 1·84). Cool, dilute with water to 500 ml. and mix thoroughly

Ammonium Citrate (50%).—Dissolve 500 g. of citric acid in 500 ml. of ammonium hydroxide (sp. gr. 0·88) and dilute to 1 litre with water.

Iodine (*N*/10).—Dissolve 12·69 g. of iodine and 25 g. of potassium iodide in as little water as possible and dilute to 1 litre.

Ammonium Hydroxide (1 : 1).—Dilute 500 ml. of ammonium hydroxide (sp. gr. 0·88) to 1 litre with water.

Dimethylglyoxime (0·1%).—Dissolve 1 g. of dimethylglyoxime in 1 litre of ammonium hydroxide (1 : 1), allow the solution to settle and filter. Store this solution in a tightly stoppered bottle to prevent any loss of ammonia by evaporation.

Procedure

Attack 0·2 g. of sample in a 250 ml. conical beaker with 4 ml. of hydrochloric acid (sp. gr. 1·16) and 10 ml. of hydrogen peroxide (100 volume), keeping the beaker cooled if the reaction becomes too vigorous. When solvent action ceases, boil gently for 2 to 3 minutes. Cool and dilute to 50 ml. using a standard flask.

Pipette a 15 ml. aliquot into a dry 125 ml. conical beaker and add 15 ml. of potassium iodide (5%) from a burette, whilst mixing thoroughly. Allow to stand for 5 minutes and then filter through a dry No. 44 Whatman filter paper into a 125 ml. conical beaker using dry apparatus. Pipette a 10 ml. portion of the filtrate into a 125 ml. conical beaker and add 1 ml. of sulphuric acid (1 : 1). Warm, remove iodine by dropwise addition of nitric acid (sp. gr. 1·42) and then carefully evaporate to fumes of sulphuric acid. Cool, add 10 ml. of water and mix. Cool, add from burettes 5 ml. of ammonium citrate (50%), 5 ml. of iodine (N/10) and 20 ml. of dimethylglyoxime (0·1%). Dilute to 50 ml. using a graduated flask and measure the extinction *A* in a suitable cell using an instrument setting of 1·0 with Ilford 604 filters. Complete this measurement within a maximum time of 30 minutes from the addition of the dimethylglyoxime solution. Return the solution in the cell to the beaker and to the latter add exactly 2 drops of hydrogen peroxide (100 volumes). Mix thoroughly and using the same cell as before obtain the extinction reading *B* of the reduced solution (Note 1). Obtain the difference between the two extinction readings *A* and *B* to give the value *C*.

Prepare a reagent blank as follows: To a 125 ml. conical beaker transfer 1 ml. of sulphuric acid (1 : 1). Add 10 ml. of water, 5 ml. of ammonium citrate (50%), 5 ml. of iodine (N/10) and 20 ml. of dimethylglyoxime and dilute to 50 ml. Measure the extinction of this solution using the same cell as used above. Return the solution to the beaker, add 2 drops of hydrogen peroxide (100 volume) and measure the extinction of the reduced solution. Subtract the difference between these two extinction values from the difference value *C* and relate this final extinction to calibration graphs constructed under identical conditions to obtain the nickel content of the sample.

Calibration

(1) *Solutions Required.*

Standard Nickel Solution A.—Dissolve 1·0 g. of spectrographically pure nickel in the minimum quantity of nitric acid (1 : 1). Evaporate almost to dryness, then dissolve by gentle warming in approximately 200 ml. of water. Cool, transfer to a graduated flask, dilute to 1,000 ml. and mix thoroughly. 1 ml. is equivalent to 0·10% nickel on a 1 g. sample weight.

Standard Nickel Solution B.—Transfer, using a pipette, 100 ml. of solution A to a 200 ml. graduated flask. Dilute to the mark with water and mix thoroughly. 1 ml. is equivalent to 0·25% on a 0·2 g. sample weight.

Standard Nickel Solution C.—Transfer, using a pipette, 50 ml. of solution A to a 500 ml. graduated flask. Dilute to the mark with water and mix thoroughly. 1 ml. is equivalent to 0·05% nickel on a 0·2 g. sample weight.

(2) *Procedure.*

(*a*) *For Nickel up to* 1·20%.—Transfer 0·15 g. portions of pure copper to each of nine 250 ml. conical beakers

(this weight is roughly equivalent to the copper content of most brasses or bronzes on a 0·2 g. sample weight). Add the following amounts of standard nickel solution C to cover the 0 to 1·2% nickel range :—

Solution C in ml.	0	2	4	8	10	12	16	20	24
Equivalent % Ni	0	0·10	0·20	0·40	0·50	0·60	0·80	1·0	1·20

Add to each beaker 4 ml. of hydrochloric acid (sp. gr. 1·16) and 10 ml. of hydrogen peroxide (100 volume) and proceed exactly as under the heading PROCEDURE. Obtain the difference extinction values using a 2 cm. cell for all solutions and a 4 cm. cell for the first six. For each cell size deduct the difference reading obtained for zero per cent. of added nickel (which serves as a blank for the reagents) from the difference values of the other synthetic standards and plot these values against percentage nickel to give calibration graphs for 2 cm. and 4 cm. cells respectively.

(*a*) *For Nickel up to* 5%.—Transfer 0·15 g. portions of pure copper to each of twelve 250 ml. conical beakers. Add the following amounts of standard nickel solution B to cover the 0 to 5% nickel range :—

Solution B in ml.	0	1	2	4	6	8	10	12	14	16	18	20
Equivalent % Ni	0	0·25	0·50	1·00	1·50	2·00	2·50	3·00	3·50	4·00	4·50	5·00

Add to each beaker 4 ml. of hydrochloric acid (sp. gr. 1·16) and 10 ml. of hydrogen peroxide (100 volume) and proceed exactly as under the heading PROCEDURE. Obtain the extinction difference values using a 0·5 cm. cell for all solutions and a 1 cm. cell for the first seven solutions. For each cell size deduct the difference value obtained for zero per cent. of added nickel (which serves as a blank for reagents) from the difference values for the other synthetic standards. Plot these values against the nickel percentage to give calibration graphs for 0·5 cm. and 1 cm. cells.

Note 1.—Care must be taken to ensure the complete dispersal of all bubbles apparent in the cell at the time of the extinction measurement so as to avoid scattering of light and resultant high extinction readings.

RESULTS

Typical results obtained on applying this method to the determination of nickel in different types of copper base alloys are given in Table II.

TABLE II.—NICKEL IN DIFFERENT TYPES OF ALLOY

Type	Nickel Percentage	
	Chemical*	By above procedure
Aluminium Bronzes		
A1	3·08	3·08
A2	3·16	3·10
A3	4·80	4·90
Brasses		
B1	0·12	0·11
B2	0·10	0·105
B3	2·81	2·80
B5	0·05	0·05
B6	1·01	1·00
Tin Bronzes		
C1	0·77	0·77
C3	0·09	0·10

* The chemical figures were obtained by precipitating the nickel with dimethylglyoxime and carefully igniting to nickel oxide.

The Determination of Manganese

The determination of this element in copper base alloys presented no difficulties on using the usual periodate oxidation procedure. In the final method the alloy is dissolved in a mixture of sulphuric and nitric acids and most of the lead in the sample is removed as insoluble lead sulphate. The manganese is then oxidised to the permanganate state with the composite potassium periodate reagent used in the determination of manganese in aluminium alloys[9]. The extinction of the resulting solution is measured and re-measured after reducing with a small amount of sodium nitrite. The difference between these two measurements gives the extinction corresponding to the manganese in the sample, and the manganese percentage is determined by reference to calibration graphs.

The Method in Detail

RANGE

0 to approximately 0·6% using a 4 cm. cell.
0 to approximately 1·2% using a 2 cm. cell.
0 to approximately 2·4% using a 1 cm. cell.
0 to approximately 4·8% using a 0·5 cm. cell.

SOLUTIONS REQUIRED

Sulphuric Acid (1 : 1).—Cautiously add 250 ml. of sulphuric acid (sp. gr. 1·84) to 200 ml. of water. Cool, dilute with water to 500 ml. and mix thoroughly.

Sulphuric Acid (1 : 3).—Cautiously add 250 ml. of sulphuric acid (sp. gr. 1·84) to 700 ml. of water. Cool, dilute with water to 1,000 ml. and mix thoroughly.

Periodate Solution.—Dissolve 20 g. of potassium periodate in 560 ml. of sulphuric acid (1 : 3). Then add 240 ml. of phosphoric acid (sp. gr. 1·75) and dilute with water to 1,000 ml.

Sodium Nitrite (2%).—Dissolve 2 g. of sodium nitrite in 100 ml. of water.

PROCEDURE

Add 25 ml. of sulphuric acid (1 : 1) to 0·25 g. of sample contained in a 250 ml. conical beaker and warm gently. Dissolve the sample by the dropwise addition of nitric acid (sp. gr. 1·42) up to a total volume of approximately 3 ml. and simmer to complete the solution. Boil gently for two minutes to remove oxides of nitrogen, then cool and dilute to 100 ml. with water using a graduated flask. Mix and stand for approximately 15 minutes to allow lead sulphate to settle, then filter about 25–30 ml. through a dry Whatman No. 40 paper, using dry apparatus. Pipette a 20 ml. aliquot into a 125 ml. conical beaker and add 4 ml. of the periodate solution. Then bring to the boil, boil gently until the permanganate colour starts to develop and continue boiling for a further 3–5 minutes. Add about 10 ml. of cold water to prevent salts crystallising out during cooling. Cool, dilute to 50 ml. in a graduated flask and mix thoroughly. Measure the extinction of this solution using a suitable cell and an instrument setting of 1·0 with Ilford 604 filters. Add 2 drops of sodium nitrite (2%) to the solution remaining in the beaker to completely reduce the manganese colour and measure the extinction of this compensating solution using the same cell as above. Determine the difference between the two extinction readings and obtain the manganese content of the sample by reference to calibration graphs prepared under similar conditions.

CALIBRATION

(1) *Solutions Required.*

Standard Manganese Solution.—Dissolve 0·7193 g. of Analar potassium permanganate in approximately 500 ml. of water and dilute to 1,000 ml. in a graduated flask. 1 ml. of this solution is equivalent to 0·10% manganese on a 0·25 g. sample weight.

Sulphurous Acid.—Saturate 100 ml. of water with sulphur dioxide.

9 Osborn, G. H. and Stross, W., "Modern Methods for the Analysis of Aluminium Alloys," London, 1949.

(2) *Procedure.*

Add the following varying amounts of the standard manganese solution to 250 ml. conical beakers to cover the range from 0 to 4% :—

ml. solution	0	1	2	3	5	10	15	20	25	30	35	40
Equivalent % Mn ..	0	0·10	0·20	0·30	0·50	1·0	1·50	2·0	2·50	3·0	3·50	4·0

Then add to each beaker 25 ml. of sulphuric acid (1 : 1) and reduce the permanganate colour by the dropwise addition of the minimum amount of sulphurous acid. Dilute the contents of each beaker to exactly 100 ml. using a graduated flask and proceed exactly as under the heading PROCEDURE. Measure the extinctions of the oxidised and reduced solutions using 0·5, 1, 2 and 4 cm. cells and plot the extinction difference readings against the manganese percentage to give a separate calibration graph for each size of cell.

RESULTS

Typical results obtained on applying this method to the determination of manganese in different types of copper base alloys are given in Table III.

TABLE III.—MANGANESE IN DIFFERENT TYPES OF ALLOY

Type	Manganese Percentage	
	Chemical*	By above procedure
Aluminium Bronze		
A1	2·36	2·36
A2	3·05	3·10
A3	0·14	0·13
Brasses		
B2	0·013	0·015
B3	0·16	0·165
B4	0·25	0·25
B5	0·035	0·035
B6	1·03	1·04

* The chemical figures were obtained by the bismuthate oxidation method and titration with ferrous ammonium sulphate.

A Composite Scheme for the Determination of Iron, Nickel and Manganese

This scheme was developed to enable the speedy analysis of copper base alloys requiring the determination of all the above elements. It consists of the preparation of a master solution from a single weighing of the alloy and the determination of the elements by applying absorptiometric procedures to separate aliquots taken from this solution. For convenience it incorporates the reagents and calibration graphs prepared in the procedures for the individual determination of each element.

The Method in Detail

PREPARATION OF THE MASTER SOLUTION

Attack 0·5 g. of sample in a 500 ml. conical beaker with 10 ml. of hydrochloric acid (sp. gr. 1·16) and 25 ml. of hydrogen peroxide (100 volume), keeping the beaker cooled if the reaction becomes too vigorous. When solvent action ceases, boil gently for 2–3 minutes. Cool and dilute to 250 ml. using a graduated flask. Pipette the following aliquots from this solution to separate beakers for the determination of the three elements :—

One 10 ml. portion for iron to a 50 ml. tall-form micro-beaker.

One 20 ml. portion for nickel to a 125 ml. conical beaker.

One 25 ml. portion for manganese to a 250 ml. conical beaker.

PROCEDURE FOR IRON

To the 10 ml. aliquot taken from the master solution add the high purity aluminium coil and boil the solution gently for approximately two minutes. Continue and complete the determination exactly as on page 272, including the preparation of the reagent blank.

PROCEDURE FOR NICKEL

Add exactly 20 ml. of potassium iodide solution (5%) to the 20 ml. aliquot of the master solution. Mix thoroughly and stand for 5 minutes, then filter through a dry Whatman No. 44 filter paper into a 125 ml. conical beaker using dry apparatus. Pipette a 20 ml. portion into a 125 ml. conical beaker, add 1 ml. of sulphuric acid (1 : 1) and a small quantity of nitric acid (sp. gr. 1·42). Remove the iodine by careful evaporation, adding more nitric acid if necessary, and then evaporate down to fumes of sulphuric acid. Cool, add 10 ml. of water and mix thoroughly. Cool, form the nickel-dimethylglyoxime colour and complete the determination as on page 273.

PROCEDURE FOR MANGANESE

Add 5 ml. of sulphuric acid (1 : 1) to the 25 ml. aliquot taken from the master solution and evaporate down to fumes of sulphuric acid to completely remove the hydrochloric acid. Cool, add 10 ml. of water and simmer gently for one minute. If lead is present, allow the solution to stand for 15 minutes, then filter off the lead sulphate on a Whatman No. 40 filter paper, washing with sulphuric acid (5%) to give a total volume of approximately 20 ml. If lead is absent, add a further 10 ml. of water to the 10 ml. of sample solution.

Add 4 ml. of periodate solution, boil the solution gently until the permanganate colour starts to develop and continue boiling for a further 3 to 5 minutes. Add approximately 10 ml. of cold water to prevent salts crystallising out during cooling. Cool, dilute to 50 ml. in a graduated flask and mix thoroughly. Complete the determination exactly as outlined on page 274.

RESULTS

Table IV shows the close agreement obtained for iron, nickel and manganese in different types of copper base alloys by the above composite scheme with the accepted chemical results for these elements.

TABLE IV.—IRON, MANGANESE AND NICKEL IN DIFFERENT TYPES OF ALLOYS

Alloy Type	Percentage of Element					
	Iron		Manganese		Nickel	
	Chemical	Composite	Chemical	Composite	Chemical	Composite
Al Bronze						
A1 ..	3·45	3·35	2·36	2·36	3·08	3·075
Brasses						
B2 ..	0·08	0·07	0·013	0·015	0·10	0·105
B3 ..	0·94	0·95	0·16	0·165	2·81	2·80
B5 ..	0·065	0·07	0·035	0·035	0·05	0·045
B6 ..	0·87	0·83	1·03	1·04	1·01	1·00
Tin Bronzes						
C1 ..	0·37	0·37	—	0·01	0·77	0·77
C3 ..	0·06	0·04	—	0·01	0·09	0·10

Conclusion

In developing these procedures the accuracy and reproducibility have been carefully considered in addition to the time required in carrying out each determination. The time taken for the completion of any one single determination is less than 45 minutes whilst it takes less than 90 minutes to complete the composite scheme. The close agreement shown in the various tables between the chemical and the absorptiometric results supports our claim that these procedures are suitable for the inspection analysis of most types of copper base alloys for iron, nickel, and manganese.

Analysis of Silver Solders by Electrodeposition

By George Norwitz*

THE procedure customarily used for the analysis of silver solders is very time-consuming[1]. In this procedure the silver is precipitated as the chloride and the copper is determined by electrolysis on the silver chloride filtrate. The cadmium is separated from the zinc by a double sulphide separation and is determined by electrolysis from a cyanide medium. The zinc is precipitated as the sulphide from a formic acid medium and is ignited to the oxide. A method has been developed by the author for analysing silver solders by electrodeposition that requires only one-fourth the time required by the above method. In the proposed method the silver is separated from the copper by use of the sodium nitrite-nitric acid medium discovered by the author[4]. The nitrite is then destroyed by boiling and the copper deposited. The solution is evaporated to fumes of sulphuric acid and the cadmium deposited under conditions specified by Holland[2, 3]. The electrolyte from the cadmium determination is then treated with an excess of sodium hydroxide and the zinc deposited. The method is designed for the usual silver solders of commerce that contain silver, copper, cadmium and zinc. It is not recommended for the analysis of silver-nickel solders.

Procedure

Dissolve a 1 gram sample contained in a 300 ml. electrolytic beaker with 20 ml. of nitric acid (1 to 1) by warming on the hot plate. Dilute to 180 ml. and add 6 grams of sodium nitrite. Electrolyse for silver for 1 hour at 2 amp. per sq. dm., using platinum gauze cathodes and platinum spiral anodes. With the current on, lower the beaker containing the electrolyte while rinsing the electrodes with a stream of water. Immerse the cathodes in water and in alcohol, dry at 105° C. for 3 minutes, cool, and weigh the deposit as metallic silver. Boil the electrolyte from the silver determination until the volume is reduced to about 100 ml. Add 1 drop of 0·1 N hydrochloric acid solution and dilute to 180 ml. Electrolyse for copper for 1 hour at 2 amp. per sq. dm., using platinum gauze cathodes and platinum spiral anodes. With the current on, lower the beaker containing the electrolyte while rinsing the electrodes with a stream of water. Immerse the cathodes in water and in alcohol, dry at 105° C. for 3 minutes, cool, and weigh the deposit as metallic copper.

Add 5 ml. of sulphuric acid to the electrolyte from the copper determination and evaporate to fumes of sulphuric acid. Wash down the sides of the beaker and again evaporate to fumes of sulphuric acid. Dilute to 180 ml and add 5 grams of sodium sulphate. Electrolyse for cadmium for 1 hour at 1 amp. per sq. dm. using platinum gauze cathodes and platinum spiral anodes. With the current on, lower the beaker containing the electrolyte while rinsing the electrodes with a stream of water. Immerse the cathodes in water and in fresh alcohol, dry at 105° C. for 3 minutes, cool, and weigh the deposit as metallic cadmium. Neutralize the electrolyte from the cadmium determination with sodium hydroxide solution (15%) and add about 20 ml. excess sodium hydroxide solution. Electrolyse for zinc for 1 hour at 1 amp. per sq. dm. using copper coated platinum gauze cathodes and platinum spiral anodes. Quickly drop the beaker containing the electrolyte and quickly replace it with a beaker containing water. Raise and lower this beaker several times and then replace it with another beaker of water. Immerse the cathodes in fresh alcohol, dry at 105° C. for 3 minutes, cool, and weigh the deposit as metallic zinc.

Precaution: Fresh alcohol should be used for rinsing zinc and cadmium deposits (especially the zinc deposits). Significant losses will occur if alcohol that has been used in rinsing the silver or copper deposits is used for rinsing the zinc or cadmium deposits. Evidently the barest trace of nitric acid has a strong solvent action on the zinc and cadmium.

Results

The results obtained by the author on two representative silver solders are shown in Table I.

TABLE I.—RESULTS FOR SILVER, COPPER, CADMIUM AND ZINC IN SILVER SOLDERS.

Sample	Contains	Found
	%	%
1	49·94 Ag	49·90 Ag
		49·94 Ag
	15·45 Cu	15·48 Cu
		15·46 Cu
	18·01 Cd	18·05 Cd
		18·00 Cd
	16·58 Zn	16·55 Zn
		16·53 Zn
2	49·80 Ag	49·81 Ag
		49·83 Ag
	15·62 Cu	15·65 Cu
		15·66 Cu
	18·32 Cd	18·28 Cd
		18·31 Cd
	16·16 Zn	16·20 Zn
		16·22 Zn

* As determined by A.S.T.M. procedure (Ref. 1).

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1 American Society for Testing Materials, "A.S.T.M. Methods of Chemical Analysis of Metals," p. 253, Philadelphia, Pa., 1946.
2 Classen, A., "Quantitative Analysis by Electrolysis," p. 113, John Wiley and Sons, New York, 1915.
3 Hollard, A., *Bull. soc. chim.*, **29**, 217 (1903).
4 Norwitz, *Anal. Chim. Acta.*, **5**, 106 (1951).

Correspondence

Electrical Conductivity of Silica

The Editor, METALLURGIA.

Dear Sir,

The present communication is intended as a warning and as a request for information.

In the course of recent experimental work with electrical resistance furnaces, in which a heating element of nickel-chromium was wound directly on to a 2 in. dia. tube of silica, it was found that at high temperatures the silica furnace tube became conducting and a potential of 60 to 100 volts was obtained between the inside of the silica tube and earth. Rough preliminary measurements suggest that the conductivity of silica becomes appreciable above about 900° C.

One practical result of this conductivity is that a bare thermocouple inside the furnace will become charged if it touches the furnace wall. Thermocouples sheathed in alumina have also been found to pick up the charge.

Further work is in progress but the writer would welcome any information which is available on this effect.

Yours faithfully,

H. J. AXON,
Lecturer in Electrometallurgy.

The University,
Manchester.

23rd October, 1951.